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Volume Fifty

This issue marks the beginning of the fiftieth volume of POPULAR ASTRONOMY. Perhaps it would be fitting to wait until the close of Volume Fifty, until a complete half century has been rounded out, before pausing to survey the course this magazine has traced. But even the *beginning* of a fiftieth volume is too significant an event to be passed by without recognition.

Founded in 1893 by Professor W. W. Payne, the magazine continued definitely under his direction and supervision until his retirement from active duties as a member of the faculty of Carleton College in 1908. Following him, his assistant, Professor Herbert C. Wilson, undertook the responsibility of managing the affairs of this magazine and continued to do so from 1909 to 1926, the year which marked his retirement. Again, following Professor Wilson, his assistant, the writer, was given charge and has continued in that position until the present. During its forty-nine years, therefore, POPULAR ASTRONOMY has had three editors, each one serving for almost exactly one-third of the period.

The world has now come upon a time when, to the best of our knowledge, the astronomical journals, except those in England and America, have practically ceased to exist. Therefore, for the sake of future study of astronomy, it is incumbent upon the American journals in this field to fulfill their responsibilities in the most efficient manner. With this in mind, the President of Carleton College, which is the sheltering institution for POPULAR ASTRONOMY, and the Editor came to the conclusion that, in the future, POPULAR ASTRONOMY would be greatly benefitted by having the advice and counsel of several recognized astronomers in the shaping of its policies and practices.

Accordingly ten astronomers, representatives of various fields and of different sections of the country, upon being invited to do so, have consented to serve as collaborators. The functions of this board have not been sharply and specifically defined. They will become clear as time goes on and as experience grows. However, it is certain that the position of POPULAR ASTRONOMY will be strengthened and its sphere of usefulness extended through this co-operation.

The names of the collaborators appear on the front cover of this issue. They are hereby introduced to our readers in this new capacity.

John Stanley Plaskett
1865-1941

By R. M. PETRIE

The death of Dr. J. S. Plaskett on October 17, 1941, terminated the career of Canada's leading astronomer and brought a deep feeling of scientific and personal loss to his colleagues and friends the world over. His astronomical work during the past four decades was an integral part of the rapid expansion that characterizes present day astrophysics, and his name will always be associated with the pioneering era of stellar spectroscopy and with the development of great reflecting telescopes for astrophysical research. In common with many outstanding men of his day, Plaskett's career is a record of accomplishments due entirely to his own ability and energy. Beginning life in a modest and ordinary environment he finally reached a position of the highest eminence in the scientific world, his achievements eliciting the admiration of colleagues and intellectual groups alike. John Stanley was born on a farm near Woodstock, Ontario, in 1865, the eldest child of Joseph and Annie Plaskett. For a time in early life he assisted in the management of the farm but, finding this work uncongenial, soon gave it up to become engaged in engineering work in Woodstock. His mechanical training was carried on with the Edison Company in Schenectady and the Canadian Edison Company at Sherbrooke, Quebec. His first contact to determine the future course of his life came in 1890 when he joined the University of Toronto staff as lecturer's assistant and foreman of the instrument shop. Experience

JOHN STANLEY PLASKETT

and practice in the preparation of apparatus for physical demonstrations led to a desire for more extensive scientific training and he enrolled as a student in the University and was graduated in 1899 with honours in mathematics and physics.

In 1892 he married Rebecca Hope Hemley. Two children were born to this union: Harry Hemley, now Savilian Professor of Astronomy at Oxford University; and Stuart S., now living with his mother at Victoria. During a long and happy married life Plaskett often paid tribute to the inspiration and encouragement given by his wife, particularly during his efforts to complete his education and scientific training.

The connection with the University was maintained until 1903 but, with the beginning of the century, new opportunities arose. At Ottawa a new observatory was being planned by the Dominion Government and Plaskett received an appointment under Dr. W. F. King, then Chief Astronomer. Here the mechanical skill and experience of the future astronomer were of great service and in many subsequent undertakings this knowledge was to prove invaluable. While at Toronto Plaskett had become absorbed in photographic work, particularly the then novel field of colour photography, and had delivered a lecture on the monochromatic renditioning of coloured subjects. This experience was soon to be put to the test. In 1905 a total eclipse of the sun occurred and Plaskett was placed in charge of the observational work of a Canadian expedition to Labrador. His was the responsibility of deciding upon the observational work and of the designing and assembling of the equipment. A detailed account of this work[1] was prepared, an intensely interesting paper and the first in a long and important list of scientific communications. Although the expedition was unsuccessful because of adverse weather, the account of the preparations shows thorough and careful consideration and a keen grasp of the essential scientific information to be sought. It is perhaps worthy of note that this first scientific venture was made at the age of forty. The mental powers, shown by his appreciation of the important scientific problems to be attacked, were already developed at the very outset of his astronomical work.

Upon the organization of the Ottawa Observatory, Plaskett was placed in charge of the astrophysical work, at first alone but later assisted by W. E. Harper, J. B. Cannon, and T. H. Parker. The instrumental resources were a 15-inch refractor and a universal spectrograph, together with a machine-shop and minor apparatus. A program of radial-velocity work was planned but preliminary tests indicated that the spectrograph was not rigid enough for this exacting task and modifications were made. Plaskett soon reached the conclusion, however, that an entirely new instrument was necessary and, with characteristic energy,

[1] *Report of the Chief Astronomer, Canada,* 1905, Appendix 5. *Trans. Roy. Ast. Soc. of Canada,* page 89, 1905.

set himself to designing a more rigid and efficient one. Through visits to other observatories and painstaking and extended tests, the proper compromises between optical and mechanical principles were reached and a new spectrograph of high precision and efficiency resulted.

The new instrument was completed in 1907 and was immediately applied to the radial-velocity observations necessary for the determination of the orbital elements of spectroscopic binaries. This work was carried on so energetically and so successfully that the Ottawa Observatory, in the space of a few years, made a substantial contribution to this branch of astronomical knowledge. About this time Plaskett pursued studies of the spectra of *Mira* and *Nova Geminorum No. 2*, and, in association with R. E. DeLury, the determination of solar rotation.

While the spectrographic program was continuing at Ottawa the realization of the need for telescopes of great aperture grew upon astronomers. This was felt most strongly, perhaps, by those engaged in the study of stellar motions, particularly the line-of-sight speeds determined by the spectrograph. This need was recognized by Plaskett and he was confirmed in his desire for an instrument of greater light-grasp by intercourse with other astronomers, especially at meetings of the Union for Co-operation in Solar Research held at Pasadena in 1910. In his Annual Report for 1911 the construction, by Canada, of a large reflecting telescope was strongly recommended. With the wholehearted support of the Chief Astronomer and numerous scientific men and societies Plaskett undertook to gain Governmental approval for the project and success was finally attained in 1913, with the ordering of the 72-inch reflecting telescope. It was decided, following a series of tests made by W. E. Harper at various points in Canada, to erect the telescope near Victoria, British Columbia.

With the telescope assured, Plaskett at once began the task of preparing specifications and supervising design. Again his mechanical training and astrophysical experience combined in a most happy manner to produce, in co-operation with The Warner and Swasey Company and Mr. John Brashear, the highly successful telescope and spectrographs of the Dominion Astrophysical Observatory.

The telescope was erected in 1918 and work with it was commenced immediately. Dr. Plaskett became the first director, with R. K. Young as his assistant; they were joined soon afterward by W. E. Harper and H. H. Plaskett, these completing the original astronomical staff.

Since the need for a large telescope for the determination of stellar radial velocities had supplied the original incentive it was appropriate that the first program should be the determination of a considerable number of line-of-sight velocities. This task was undertaken as a co-operative enterprise by the new observatory staff, and completed in a remarkably short time; in 1924 the radial velocities of 594 stars were published. Thereafter Plaskett devoted himself largely to radial-velocity studies of the high-temperature, O- and B-type stars. Following the

completion of the first general program he determined the orbital elements of a number of spectroscopic binaries and this was followed by an important survey of the O-type stars based upon their motions and luminosities. During the remainder of his career at Victoria his attention was directed to the determination of the line-of-sight velocities of a large number of B stars. This heavy program of observation, measurement and, later, calculation, was shared by J. A. Pearce, who joined the observatory staff in 1924. This work, and its applications, will remain as the first extensive and accurate contribution to our knowledge of the galaxy and galactic rotation, from radial-velocity data.

Toward the end of his directorship at Victoria, Plaskett became the recipient of many honours in recognition of his contributions to human knowledge. Among the honours awarded by societies are: the Gold Medal of the Royal Astronomical Society, the Draper Medal of the National Academy of Science, the Rumford Premium, the Bruce Medal, and the Flavelle Medal of the Royal Society of Canada. Honorary degrees were conferred by several universities.

Retirement from the directorship of the observatory came in 1935, but he continued to be actively interested in astronomy. For some years he acted as scientific consultant to The Warner and Swasey Company and supervised the final figuring of the great mirror for the McDonald Observatory. His frequent visits to the observatory were a source of plesaure to the staff who enjoyed many keen and helpful discussions regarding individual researches. All were deeply grieved when it became evident that his health was failing; his quiet passing came as a personal loss.

A detailed description of Plaskett's services to science would be out of place here but a brief recapitulation may be made. A detailed bibliography has been given by Beals[2]; the principal scientific contributions number more than sixty papers, together with a number of shorter communications and non-technical writings.

One of the principal contributions must be considered to be his study and design of astronomical instruments, more specifically the stellar spectrograph and the large reflecting telescope. His researches on the mechanical and optical properties of spectrographs attached to telescopes are still of value to the worker in spectroscopy. Their more immediate result was to enable the Ottawa astronomers to take a leading part in astrophysical work before the advent of the great reflectors. In the Victoria telescope and spectrographs a successful and efficient instrument became the pattern, in some respects, for succeeding construction and greatly added to the rapid accumulation of scientific data.

Contributions to observational astronomy are largely in the field of stellar radial velocity. Here Plaskett exhibited great energy and productivity. The determination of the radial-velocities of several hundred

[2] *Journal Roy. Astron. Soc. of Canada*, 1941 (in Press).

stars, and the observation and calulation of the orbital elements of many binary stars will remain as permanent monuments. The investigation of the structure and dimensions of our galaxy marks an epoch in such studies and stimulated further observation and progress.

The account would be incomplete without some mention of Plaskett's influence upon the development of Canadian Astronomy. The founding of a major observatory placed Canada in an enviable position in the astronomical world and awakened pride and interest in her national contribution to science. More intangible, but perhaps not less important than his astronomical observations, was his stimulation of public appreciation of astronomy through numerous and appealing popular lectures. The interested layman was always welcomed to the observatory; the writer has been told, on many occasions, of the kindness and courtesy which met visitors to the institution. The general respect and admiration felt for him disposed the public to regard astronomy in a kindly light.

In closing, a personal tribute may be permitted. Dr. Plaskett was always eager to assist students with helpful advice and encouragement, and by extending to them the facilities of the observatory. The writer will be sensible of a life-long debt of gratitude for assistance, freely and generously extended, at a time when it was most needed.

VICTORIA, B. C., DECEMBER, 1941.

The Maya Calendar

By MAUD WORCESTER MAKEMSON

The Maya tribes of Yucatan and Central America long ago lost the knowledge of interpreting the hieroglyphic inscriptions found on the fallen monuments and temple walls of the ruined cities which now lie buried in the jungle. Yet their ancestors once possessed the most highly developed civilization of the American continents, comparable in its achievements in the arts and sciences with the early civilizations of the Old World. Even before the Spanish Conquest completed the destruction of their former glory, inter-tribal warfare had brought them under the domination of the Aztecs, and the golden era of Maya culture was already a thing of the past.

No traces of contact between the Maya civilization and those of Europe and Asia have come to light, and one must conclude that it developed along independent and original lines, uninfluenced from a world outside their own small area. In mathematics and astronomy the Maya had achieved remarkable advances. They invented the *zero* and the use of position to give value to a number, centuries before these devices found their way into Europe from the Orient, and perhaps a long time before they began to be used in India. They possessed a simple system of number symbols which make the Roman numerals appear

most cumbersome by contrast. They indicated that a number was to be subtracted, by placing a ring around it.

The Maya did not use fractions or decimals, but they ingeniously avoided the necessity for such numerical devices by finding the smallest number of multiples of a fraction which gave a whole number, indicating that they were perfectly familiar with the principle involved. For example, the best known value today for the length of the synodic month—the interval from new moon to new moon, is

29.530588 days.

The Maya had no way of expressing this fact directly, since they did not use decimals. Instead, they tried to determine how many synodic months equaled an integral number of days. Two such lunar equations may be cited to illustrate the method. From Copan, a great southern city which was probably flourishing during the early centuries of the Christian era, we have

149 lunations = 4400 days;

and from Palenque, a rival city,

81 lunations = 2392 days.

Dividing 4400 days by 149, and 2392 days by 81, gives us the following values for the length of the synodic month according to ancient astronomers of Central America:

Copan 1 month = 29.530201 days
Palenque 1 month = 29.530864 days.

Thus the Palenque value, which is also found in the Maya manuscripts, is a little closer to the true value, but both were remarkably accurate and served for long-time eclipse predictions.

In the same manner the Maya had discovered by careful observation that five consecutive synodic revolutions of the planet Venus run as follows: 580, 587, 583, 583, and 587 days, totaling 2920 days. This gave them the equation

5 Venus periods = 2920 days.

Since 2920 days equal eight calendar years of 365 days, the equation formed the basis of predictions of apparitions of Venus in the morning or evening sky, over a long period of years. Several pages of the so-called Dresden manuscript, written in Maya hieroglyphs, are occupied by tables of Venus, and include a multiplication table built upon this basic period, containing multiples up to $13 \times 2920 = 37{,}960$ and multiples of 37,960 up to 151,840 days or more than 400 years.

The native sources for information regarding the ancient Maya which are available for study today may be divided into three classes:

1) the several hundred inscriptions found on stelae and on the outside and inside walls of buildings, including a few on pottery and other objects.

2) the three manuscripts known as the Codices which are all that remain of the extensive pre-conquest literature, written in Maya hiero-

glyphs on durable paper or parchment.

3) about 16 chronicles written in the 16th and 17th centuries in the Maya language but in Spanish script, containing history and mythology and other valuable information.

In 1548 a fanatical Franciscan friar, known to posterity as Bishop Landa, was sent to Yucatan to convert the Maya to Christianity. In pursuit of his duties he forcibly seized all the native books he could lay his hands on and burned them, "to the great distress of the natives." In 1562 he was recalled to Spain to stand trial before the Council of the Indies for his cruel acts, and while awaiting trial he tried to justify his behavior by writing an account of the history, customs, and religious observances of the Maya as he had learned of them from native scholars.

Fortunately Landa gave information about the calendar which has proved most valuable. He recorded a typical Maya year in terms of a current Julian year which modern students have shown must have been 1553-54, and he gave the names and hieroglyphs of the days and months. He made two statements regarding the Maya calendar which have proved to be false, probably due to his own limited understanding: he said that the Maya year always began on July 16 and that a day was intercalated every four years to form a leap year as in the Julian calendar to which he was accustomed.

The three manuscripts which escaped Landa's zeal turned up eventually in Dresden, Madrid, and Paris, respectively, and are known now by the names of those cities. They consist of long sheets of paper folded several times like a screen to form pages of a convenient size. The scribe often wrote horizontally across several of these pages. Landa informs us that the paper was made of pounded and macerated bark or the leaves of the maguey and that the folded book was enclosed between two decorated slabs of wood for its better preservation. Twenty-seven rolls of parchment, covered with hieroglyphic writing, were among the hundreds of books destroyed by Landa. Of the three extant books the Dresden Codex is in the best state of preservation. The writing and drawings are delicately executed with a lavish use of color, and the subject matter treats of rituals and ceremonies and of astronomical and astrological predictions.

Inscriptions are found in the ruined cities from Chiapas, Mexico, to Guatemala and Honduras and in Yucatan. Many of these are unfortunately past deciphering.

The Chronicles, written in the Maya language but in Spanish script, indicate a last desperate effort to preserve the traditional learning before it was lost forever. These manuscripts, which were probably far more numerous two centuries ago, are called the Books of Chilan Balam, the name of an order of priesthood. They may be copies of much earlier manuscripts for the historical records contained in them go back for more than 1000 years.

The Chronicles are of no aid in deciphering the hieroglyphs, of

course, and about two-thirds of the latter are still to be interpreted. All the glyphs now known have to do with numbers, the calendar and astronomy, and archaeologists fear that the remainder may prove to serve a similar function. Not a single glyph for the name of a city or individual is known. The fact that the same characters are found throughout the Maya area seems to indicate that the inscriptions do not record local history but astronomical phenomena common to all localities.

Before entering upon the details of the calendar as it is known from the inscriptions, the codices, and the writings of Bishop Landa, we must first examine the number system. In the simple or normal method numbers were indicated by dots and bars. One dot stood for 1, two for 2, and so on up to five which was represented by a bar. Six consisted of a dot over a bar, seven of two dots over a bar and so on up to 10, which was indicated by two bars.

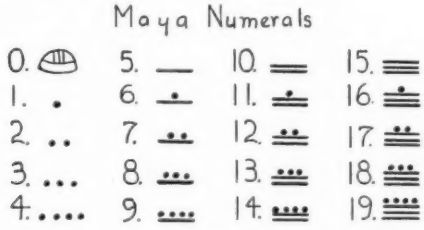

FIGURE 1

Now instead of using a decimal system as we do in our so-called Arabic notation, the Maya counted by 20's, the number of fingers and toes on the human body. So after 19, which consisted of four dots over three bars, the next number was indicated by a 1 in the second place followed by a zero. Spinden believes that before the invention of writing, the count was made by means of beads, sticks, and shells. In writing, the bead became a dot, the stick a bar, and the symbols for zero and 20 resemble shells. The symbol for 20 is also a form of the glyph for Moon, and we shall see later that the Maya "month" was composed of 20 days.

For commerical transactions a straight vigesimal system was apparently maintained into the higher numbers; thus 20 of the first place equaled one of the second; 20 of the second made one of the third, and so on. So that the series ran as follows:

1- 0 = 20
1- 0- 0 = 400
1- 0- 0- 0 = 8000 etc.

In the calendar count of days, however, there was one exception to this rule and that was in the third place, where the Maya counted 360 days as making the next higher unit, instead of 400 days. Very likely they considered this period of 360 days, called the *tun* (stone), as the

basic unit of the count, rather than the *kin* or day. Thus the fourth place consisted of 20 *tuns* or 1 *katun,* and contained 20×360 days $=$ 7200 days. In tabular form the count of days was as follows:

1 kin	= 1 day			
1 uinal	= 20 days			
1 tun	= 18 uinals	=	360	days
1 katun	= 20 tuns	=	7,200	days
1 baktun	= 20 katuns	=	144,000	days
1 pictun	= 20 baktuns	=	2,880,000	days and so on.

In terms of a year of 365.25 days, the *katun* thus contained 19.71 years, the *baktun* equaled 394.25 years, and the *pictun* was 7885.0 years in length. These figures give some idea of the enormous time-scale conceived of by the Maya in their calendrical calculations.

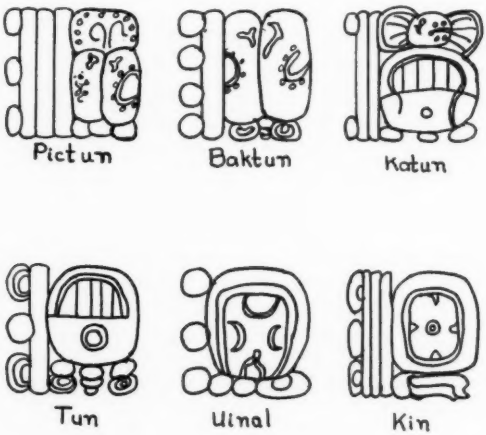

Fig. 2. Glyphs for the first six orders of time-periods.

The glyphs are shown with their numerical coefficients. (After Teeple: Contributions to American Archaeology of the Carnegie Institution, Vol. I, Washington, 1931.)

FIGURE 2

To refer to the lunar equations previously cited, the Maya method of writing the 4400 days was

12- 4- 0

which they read "12 tuns, 4 uinals, 0 kins." While the 2392 days of the Palenque lunar equation was indicated by

6-11-12

and read "6 tuns, 11 uinals, 12 kins." In the codices, these numbers were written in a verical column, the highest period being at the top. Figure 3 compares the Maya method of writing 2392 days with the Roman system.

FIGURE 3

Practically all Maya inscriptions begin with dates, which consist of a count of days, uinals, tuns, katuns, and so on from a certain normal date far in the past, just as we designate a date by a count of days, months, and years since the beginning of the Christian era. The chief difference is that while we count our years in *current* time, they counted their periods in *elapsed* time. When we say that this year is 1941, for example, we mean that the 1941st year since the beginning of the Christian era is still current; but the Maya would have called this year 1940, signifying that 1940 years have been completed, and that the 1941st year is still current.

They were perfectly consistent about this convention of counting always in elapsed time, while we are not; for we are always most particular to give our ages in elapsed years only. And also, when we say that it is 10:30 A.M., we mean that 10 hours and 30 minutes have actually elapsed since midnight, and the 11th hour is still current. On the other hand, when we say today is March 10, we mean that the 10th day of March is still going on.

The Maya Long Count, or count of days from the normal date, is so perfect a machine that if we today were able to fix a single one of their dates in our calendar, all other dates would fall into place like clockwork; whereas archaeologists of 2000 years hence, studying our own calendar, will discover a number of puzzling and abrupt breaks in it.

A typical date on a Maya inscription of the golden age of their civilization is one like 9-10-0-0-0, 1 Ahau 8 Kayab, which states that 9 baktuns of 144,000 days, and 10 katuns of 7200 days each, have elapsed since the normal date, corresponding to 3745 Julian years of 365.25 days each. Although the Long Count alone was sufficient to fix a date exactly in an infinite range of time, it was customary to affix the name of the day and the day coefficient as well as the name of the month or uinal and the position of the day in this period. It is fortunate for modern archaeologists that such a check was used, because when part of a date is obliterated it is still often possible to reconstruct it from the day and month names and their numbers.

In our calendar we use an arbitrary count of seven days which has come down to us from the Chaldean astrologers, and which repeats endlessly regardless of where it may fall in the month or year. Our months, on the other hand, are variable quantities ranging from 28 to 31 days each and our year may have 365 or 366 days.

In the Maya scheme, the uinal consisted of 20 days, each having its name and hieroglyph, and before each day-name was prefixed a number ranging from 1 to 13. Thus if a certain uinal began with a day 1 Imix, the next day was 2 Ik, the third was 3 Akbal and so on to 13 Ben. The 14th day Ix was then given the number 1, the 15th was 2 Men, and so on. The 20th day was 7 Ahau and the following uinal then began with 8 Imix.

It will be seen from this arrangement that by the end of 13×20 or 260 days, each day name will have been coupled in turn with each of the 13 numbers, and the count will again have arrived at a day 1 Imix. Then the whole pattern is repeated. Thus the unique device of coupling 13 numbers repeatedly with 20 day names led to a time period of 260 days which the Maya called the *tzolkin* or "count of days." The Aztecs also used this period, which they may have borrowed from the Maya, but they did not have the Long Count.

The following table illustrates the *tzolkin*:

No.	*Day-name*	*No.*	*Day-name*	*No.*	*Day-name*
1	Imix	11	Chuen	8	Imix
2	Ik	12	Eb	9	Ik
3	Akbal	13	Ben	10	Akbal
4	Kan	1	Ix	11	Kan
5	Chicchan	2	Men	12	Chicchan
6	Cimi	3	Cib	13	Cimi
7	Manik	4	Caban	1	Manik
8	Lamat	5	Eznab	2	Lamat
9	Muluc	6	Cauac	3	Muluc
10	Oc	7	Ahau	4	Oc etc.

The *tzolkin* undoubtedly played an important part in ritual and astrology since a great part of both the Dresden and the Madrid codices is given over to various arrangements of this period. Pictures accompanying these *tzolkins* show gods and human beings in various occupations.

We see, then, that a day name plus its numerical coefficient fixes a date uniquely within a period of 260 days. We have no parallel arrangement in our own calendar. But in addition to the *tzolkin* the Maya also recognized a calendar year of 365 days, which was divided into 18 uinals of 20 days each plus five unlucky days at the close of the year. Landa said these were called "nameless" days, but it is clear from a great mass of evidence that the series of day names and numbers continued on without break through these five odd days which, added to the *tun* of 360 days, completed the calendar year. The five days were called *uayeb*, "couch of the year."

Just as we would say Thursday February 20, fixing the position of

the week-day in the month, so the Maya attached a number to indicate where a certain day occurred in the uinal. Instead of running from 1 to 20, however, these numbers ranged from 0 to 19, in harmony with their system of counting only completed time. The first day of their year was thus called 0 Pop, the zero indicating that the first day of Pop was yet current.

The names of the uinals were as follows:

Pop	Xul	Zac	Pax
Uo	Yaxkin	Ceh	Kayab
Zip	Mol	Mac	Cumhu
Zotz	Chen	Kankin	(Uayeb)
Tzec	Yax	Muan	

The use of two concurrent periods—the 260-day *tzolkin* and the 365-day year—gave rise to still another period at the end of which the same day and day number could occupy the same position in a given month. This period consists of 18,960 days and contains 52 years of 365 days or 73 *tzolkins* of 260 days, without remainder. The Maya name and glyph for this period is not known but it is usually called the Calendar Round to distinguish it from other periods.

The Aztecs also recognized the Calendar Round and they expected the world to come to an end at the expiration of such a period, at the very instant when the Pleiades reached the meridian at midnight.

In earliest times the Maya may have recorded their important dates on tablets of wood, but if so, these have long since perished. The oldest known contemporaneous date is found inscribed on a small figurine of jadeite, called the Tuxtla statuette from the locality of its discovery. The date is 8-6-2-4-17 followed by indecipherable day and month hieroglyphs with their coefficients. Another ancient date was found inscribed on a stone slab plowed up near the shore of the Gulf of Honduras, which is called the Leyden plate. The date, 8-14-3-1-12 is about 158 years later than that of the statuette, and belongs to the same katun as the earliest contemporaneous date found on a monument, *i.e.,* the 8-14-10-13-15, 8 Men 8 Kayab on Stela 9 of Uaxactun, in the heart of the Yucatan peninsula, which points to the great antiquity of that city.

Beginning at the close of baktun 9, stelae were erected to commemorate the completion of katuns, half-katuns, and even quarter-katuns, *i.e.,* at the close of 20, 10, and 5-year periods, approximately. Since these monuments were apparently dedicated on the period-ending day they must have been prepared in advance of the date on which they were set up. This process involved quarrying the stone, perhaps at some distance from the city, and transporting it to the site. Some of the monoliths weigh up to 50 tons. Then the priests computed the dates to be inscribed, including the age of the moon and the number of the moon in a half-year period and probably the times of other astronomical phenomena whose glyphs have not yet been deciphered. Designs were drawn for the faces and sides of the monument to be executed by the sculptors on the stone. Probably colors were applied as a final touch.

Thus the frequency with which these monuments were erected was an indication of the peace and prosperity of a city. As time went on the style of execution became more elaborate and the workmanship of higher quality.

At Copan, a great southern city in Honduras, the earliest inscribed dates thus far found were

9- 2-10- 0- 0
9- 4-10- 0- 0
and 9- 6-10- 0- 0

all commemorating ends of ten tuns or half-katuns. The last contemporaneous date in this city was 9-18-10-0-0, or 365 years after the earliest monument. After that date this flourishing city, with its great temples and other architectural triumphs, appears to have been completely abandoned after having been occupied for at least four centuries. Piedras Negras had been abandoned a hotun (about five years) earlier, and Quirigua, Uaxactun, and other great cities suffered the same fate by 10-2-0-0-0. Meanwhile, Chichen Itza in northern Yucatan had been founded in 9-17-0-0-0, showing that there was a northward movement of population for the purpose of establishing colonies and building new cities.

Various theories have been advanced to explain this tremendous exodus. One explanation is that the soil became exhausted and could not produce enough corn to support the population. The system of agriculture involved permitting the stalks to dry in the field and then burning them off. Since by this method the soil was continually depleted, two crops being raised during the rainy season without replenishing the soil by fertilization, exhaustion was bound to follow in the course of time.

The Maya dates have been cited without their equivalents in our own calendar because, as yet, no completely satisfactory correlation between the two calendars has been achieved. This is due to the unfortunate fact that the Long Count was abandoned during baktun 11, the last contemporary date found on a monument being

10-3-0-0-0.

In the later period of Maya history, the method appears to have been merely to record the katun-ending day with its number.

The normal date, 13-0-0-0-0 4 Ahau 8 Cumhu, from which the Long Count was calculated, is a curiosity in itself. It ends a certain baktun 13 which must have been counted from another date remote in the past, about 5000 years earlier than the normal date itself. The strangest thing about it is that the next baktun after baktun 13 was numbered 1, so that for all practical purposes the normal date may be considered as 0-0-0-0-0 4 Ahau 8 Cumhu. At first glance this would certainly appear to indicate a break in the vigesimal system, but there is sufficient evidence to prove that 20 baktuns were required to make up the next higher unit, the pictun. Morley has suggested that the baktuns were given the coefficients 1 to 13 like the 20-day names, which is a

plausible explanation.

According to the two most important correlations, those of Spinden and Goodman, the normal date 13-0-0-0-0 fell on the following dates in the Julian calendar:

Spinden	Oct. 14, 3373 B.C.
Goodman	Aug. 12, 3113 B.C.

These two correlations, differing by nearly 260 years, were based on the same historical data of the Chronicles and other 16th century sources and their disagreement indicates the vagueness and inconsistency of the statements and the great difficulty of harmonizing and interpreting them. Archaeological evidence from art, architecture, and pottery gives the greater support to Goodman's date.

It may be of interest to compare the dates of the great periods of Maya history on the basis of the two correlations. The following were taken from Morley's *Inscriptions of Copan,* except for the column containing the dates on the Goodman correlation:

Monument dates	Spinden	Goodman
Old Empire		
9-14-15- 0- 0 12 Ahau 8 Uo	73 A.D.	333 A.D.
9-10- 0- 0- 0 1 Ahau 8 Kayab	374	634
Middle Period		
9-10- 5- 0- 0 7 Ahau 3 Pax	378	638
9-15- 0- 0- 0 4 Ahau 13 Yax	472	732
Great Period		
9-15- 5- 0- 0 10 Ahau 8 Chen	477	737
10- 2-10- 0- 0 2 Ahau 3 Chen	620	880
Founding of Chichen Itza		
9-17- 0- 0- 0	511	770

It will be seen from this brief introduction to the scientific achievements of the Maya that one of the most fascinating pages in the history of the American continents was written by these people in the early centuries of the Christian era. While great progress has been made in the past fifty years in deciphering the codices and inscriptions, many puzzles yet remain to be solved and we may well wonder what further astronomical secrets they contain.

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Marvelous Voyages—I

Jules Verne's Journey to the Center of the Earth

By LAURENCE J. LAFLEUR

The story of a trip to another world offers the writer of fiction not only a somewhat novel and romantic setting for a tale of adventure, but also at least three opportunities for serious thought. One of these is along sociological lines, and as such is not of primary concern to us. The writer may picture a society which is better than our own in some or all respects, thus indirectly suggesting human reformation. Thus in describing a community of ant-like creatures on the moon, H. G. Wells describes the adaptation of workers to their particular jobs to the complete exclusion of everything else; Cyrano de Bergerac describes a system of sexual freedom unheard of at the time he wrote, and Swift an ideal community of horses. The writer may, on the other hand, give the subject ironic treatment by exaggerating human faults, as Swift did throughout the greater part of Gulliver's Travels, or as Burroughs did in a descrption of a Martian religion.

The sociological implications of these tales, however, are of less interest to us than are their implications in the fields of astronomy, physics, and biology. When dealing with another planet the writer must describe not merely such well-known facts as its size and periods of rotation and revolution, but also the more recondite points of its surface gravity, atmospheric density, chemical composition, and climatic changes; the appearance of the solar system from this planet; and all the interactions of these factors on each other and upon the human observer. The author must also consider what life, if any, exists upon the planet, together with the adaptations of this life to all the peculiar conditions of the planet, and the adaptations of some of this life to the nature of the rest.

The third and final opportunity comes in the voyage itself. How do human beings get to the world in question: by balloon, plane, rocket, or by some novel method of transportation? What speed can be attained, how can the direction of flight be governed, what will happen to the voyagers during the trip, and how can they effect a safe landing? These problems are quite as difficult to handle as those of the previous type, and are quite as interesting.

No writer can hope to solve all the difficulties involved in a marvelous voyage, but if he is at all serious he hopes to propose a solution that might be along the correct lines and which is consistent with the physics, chemistry, biology, and astronomy of his own day. It is because of this requirement that the consideration of scientific fiction is of such great interest to the scientific reader: it offers him an opportunity to exercise his scientific knowledge and judgment in pitting himself against the

author of the story. Errors are inevitable: it is a challenge to the reader to find them.

In the series of articles now commencing, we will describe some of these voyages to the moon, to Mars and other planets, and to the center of the earth; not of course in their literary fulness, but in such outline as will enable the reader to judge the scientific applications and speculations which give it its major interest. In reading it, the author hopes that you will pick out as many flaws as you can and keep a record of them. If you please to do so, send your list of errors to the editor. The best descriptions of the errors will be published, and credit for all solutions given in a later issue.

A Journey to the Center of the Earth (Jules Verne)

Writing in 1867, Jules Verne describes how the German professor of geology, Lidenbrock, and his nephew, Axel, discover an ancient communication from the Icelandic savant, Saknussemm, purporting to describe a trip which the latter took to the center of the earth. Following the instructions contained in this communication and indications left along the route, the two men, accompanied by a native guide, descend the crater of an extinct volcano in Iceland. After they reach sea level they find a corridor leading in a generally southeasterly direction and downwards at an angle of 45 degrees. This they follow for a little more than a month, with comparatively few incidents. Once they lose a few days by following the wrong corridor. Then they almost die of thirst, but the guide hears a subterranean river, and uses his pick to hole through three feet of rock. The jet of boiling water, after cooling, not only enables them to quench their thirst, but forms a rivulet which serves in the future as a guide to lower regions and a guarantee against thirst. Finally, just before the end of the corridor is reached, Axel is lost. He reaches a spot, however, where he can hear his uncle through some curious acoustic effect, and they converse. By timing the interval between a pronounced word and the reply to it, and knowing the speed of sound, they determine the distance which separates them, which turns out to be four miles. It develops that at this point the corridors multiply before debouching on an interior sea, somewhat as a river forms a delta before entering the ocean, and Axel is able to work his way down and rejoin his companions.

The underground sea, fed by many streams, is situated some 1000 miles horizontally and 100 vertically from their start. It is of enormous size, and they subsequently are able to travel 1500 miles on its surface. An enormous cavern contains this ocean, lit by some variety of electrical phenomenon which is supposedly due to the great pressure to which it is subjected. Far above, the vault is hidden by clouds which sometimes develop rain; and other phenomena resembling surface phenomena are encountered, such as hot springs and twelve foot tides. Professor Lidenbrock develops the theory, evidently accepted by Jules Verne,

that at some time in the past when the earth's crust was elastic, it was subject to vertical pulsations as a result of the law of gravitation, which caused the depression of part of the earth's surface to form this cavern. In accordance with this theory the local rock formations are sedimentary and the flora and fauna characteristic of the Mesozoic period. The travellers encounter forests of mushrooms 30 or 40 feet high, forests of Cretaceous types, primitive algae and fish, and many varieties of the dinosaurs of the Jurassic. They even observe and become involved in a battle between a plesiosaurus and an ichthyosaurus, and later find a plain almost completely covered with bones, many of which they recognize. They are startled, however, to recognize the corpse of a modern-type man, and later to observe alive a human giant more than 12 feet in height, engaged in herding a troop of mastodons.

Despite the absence of any indication whatsoever of the continuation of Saknussemm's path, Professor Lidenbrock decides that it lies across the ocean, and they embark upon what proves to be a 1500 mile crossing leading miraculously to the continuation of the Saknussemm corridor. Their compass, which points upwards to the north pole, suggesting that the pole is not far below the earth's surface, is affected during an electrical storm by the approach of a fire-ball, subsequently confusing the travellers by reversing north and south. The storm wrecks their raft, and a number of their instruments are lost. Fortunately, however, their manometer is saved, which will enable them to know when they reach the earth's center.

The new downward route is found to be blocked by a huge boulder, and in attempting to blast it out of the way, they open the route for the underground sea, which then pours down into the caverns below, bearing with it the raft and the voyagers. After gliding and falling at a rate of 85 miles an hour for many hours, the waters begin to rise, rising faster and faster as time goes on. The rising temperature and occasional shocks apprise them of the fact that they are underneath an active volcano. Beneath them the water boils away, so that they are left floating on a sea of lava. Before they succumb to the awful heat, however, the eruption deposits them safely on the flanks of Stromboli, bringing their marvelous voyage to a safe if not a completely successful issue.

EDITOR'S NOTE: *In order that the reader may have in mind the nature of the errors to which the author of the above paper wishes to call attention, a list of the errors noticed by the author himself is given in this instance. In subsequent papers the author's list will be withheld until readers may have had time to submit their lists. Other errors in this paper and any in future similar papers, which are reported to the editor, will be published with credit to the sender, if deemed to be of sufficient importance.*

ERRORS NOTED BY DR. LAURENCE J. LAFLEUR

1. A descent at an angle of approximately 45 degrees will not take one 1000 miles horizontally and only 100 vertically. The suggestion of the original story, incidentally, is that the descent is if anything steeper than this.

2. The river would not be a very good guide to lower regions. If the corridor turned upwards for even a slight distance the water would block the passageway completely.

3. The speed of sound in air varies according to density and pressure. Verne's assumption is that the pressure underground does not differ greatly from that at the surface. But if an ordinary conversation can be heard at four miles, one would suppose that the air must have better acoustical properties due to enormous pressure, or else that the medium of the sound waves is not air at all, which would make calculation of distance impossible.

4. Deltas are formed due to the fact that the waters of a river slow down as they meet the sea, and thus deposit sediment. No delta is to be expected if a river reaches a sea through a vertical path.

5. The underground sea is pictured as fed by many streams. If water enters the sea, water must leave. The presumption would be that water evaporated in the cavern, was carried by air up into the corridors, where it condensed to form streams which flowed down to the sea once more. But if this occurred, the corridors would be damp as a normal condition.

6. A cavern as enormous as that described probably could not exist in the earth. It is at least 1500 miles wide in a direction chosen at random, and no other shores were visible at any time during the passage. At the edge it was high enough to give the appearance of a normal cloudy sky, and was presumably even higher towards the center. All this must not only exist 100 miles underground, but must withstand the earth slippages which produce earthquakes.

7. The meteorological phenomena—such as clouds and rain—are unlikely in an underground cavern, however large. It is variation in the amount of radiation received from the sun, produced by the earth's revolution and rotation, which causes the weather phenomena of the surface. Other causes of differentiated conditions might exist underground, but the whole tempo should be slower, and the variation in conditions less.

8. Twelve-foot tides are indicated with no unusual coastal conditions to cause them. But tides are produced by the slightly greater pull of the moon on points of the earth nearer to it, and this difference would be less, and the tides consequently smaller, if the radius of the earth were less. The tides to be expected underground are therefore less, not greater, than those on the surface.

9. "Vertical pulsations as a result of the law of gravitation" is pure nonsense.

10. If any part of the earth's crust were folded in, it would produce changes of considerable size in the geological characteristics of the solid earth, but it would not produce a cavern. Even if it did, the violence of the change would hardly permit the animals living on the enfolded crust to continue living, nor would it provide them with the continuity of climate required for their offspring to live.

11. If Mesozoic flora and fauna were enfolded, they would have produced new varieties in the intervening time. There is no reason to expect evolution to cease just because it is underground.

12. But if Verne supposes a Mesozoic flora and fauma, he should at least be consistent, and not introduce the skeleton of a modern man.

13. The giant man never did exist, of course.

14. The mastodon does not belong in a Mesozoic fauna.

15. Fields full of bones are found in modern investigations. But when the bones were deposited these fields were the beds of rivers, not burial grounds, for which Verne has mistaken them.

16. The earth's crust has been substantially the same for at least two billion years. Consequently, if a folding-in occurred when the crust was significantly more "elastic" than at present, it would be in the Azoic, not the Mesozoic period.

17. That Lidenbrock and Saknussemm should both wander without direction over 1500 miles of ocean, and arrive at precisely the same point, is rather overpowering as a coincidence.

18. A compass does not point to the north pole; it lies in a line of force. No indication that the pole lies not far beneath the surface could be given by the position of the compass needle.

19. A manometer would not show them when they were at the center of the earth; particularly since Verne assumes for his own purposes that the pressure underground is less than would be expected. If they could tell at all, it would be because of the complete absence of any gravitational effect.

20. Human beings would not expect to be alive after going over Niagara Falls. These voyagers were falling in a worse cataract for many hours.

21. They not only float without harm on a sea of boiling water, but are still unharmed on a wooden raft on a sea of molten lava after the water has all boiled away: unharmed even when they are erupted from the crater and deposited on the flanks of the mountain. When Mt. Pelée blew off its top in 1902, the whole population of a distant city was killed by the withering heat.

22. If caverns and corridors existed in the earth's interior, there is

no reason why they should connect with each other, unless there were so many that the interior was practically spongy, which is not the case.

23. If caverns and corridors existed in the rock, they would not remain air filled, but would soon fill up with oil or water.

24. If large caverns existed fairly near the surface—as large as Verne describes—the force of gravitation on the surface would be detectably lower.

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Predicting Minima of Algol

By MARY R. HUNT

Although Algol is one of the best-observed variable stars in the sky, it is also a difficult one to know much about. It *is* known, however, that it is incorrect to think of it as a single star, for the light variations have been known for many years to be due to a secondary component. The second body is not entirely dark, as was one thought, but does give off some light of its own. This was ascertained by the photoelectric observations which were of sufficient photometric accuracy to show a small secondary minimum. It has also been known for many years that the period of light variation of the system is not regular. This irregularity is now ascribed with considerable certainty to the presence of yet a third body. It was, thus, with some interest that we undertook to observe accurately the time of a photographic minimum of Algol. Only three minima were available to us, in the time at our disposal, and unfortunately weather and mechanical difficulties prevented successful observations. In the course of the work, however, an attempt was made to check the prediction of time of minimum on March 6. It was then that we noticed that the predictions for this minimum were not the same in the *Observer's Handbook* and the *B. A. A. Handbook,* but differed by about forty-three minutes. A search for the cause behind this effect has led through all the literature, available to us, on the subject of the period of Algol and the problem of predicting minima.

Without discussing the history in too much detail we may mention several interesting points:

1. There is wide variation in the formulae presented by various workers as to the most satisfactory solutions of the data considered. The procedure in general, if we oversimplify the mathematics involved, is to divide the time interval, between the first and last minima considered, by the required number of epochs, in order to obtain the mean period, and then to add to this mean period various sine or cosine terms that will most closely approximate the other observations. Some investigators have two such terms,[1] others have had as many as five.[2] Besides varia-

tion in the formulae, there is a range of about eighteen seconds in the length of the mean period.

2. The third body, evidence of which is found in the spectrograms of Algol, would distort the orbit of the two-star system, that is responsible for the eclipses, in a way very difficult to predict, and errors between the observed and computed times of eclipse would easily be appreciable on this account. Schlesinger's discussion of "The Problem of Algol"[3] in 1915 points out that two "third bodies" have been discussed. The first was the one suggested by Chandler, introducing into the formula a term with a period of 131 years. This long-period term lost favor subsequently as radial velocities showed a new oscillation, of period slightly less than two years, and induced the hypothesis of an "entirely different third body."[4] There has also been a suggestion that four bodies may be physically associated.[5]

3. Sterne has pointed out[6] that if one considers statistically all the observations available up to 1931, two periods are required to fit the times of minima satisfactorily. A longer period ($2^d.8673429 \pm 0^d.0000057$ m.e.) applies from 1782-1840, a shorter period ($2^d.8672861 \pm 0^d.0000046$ m.e.), from 1840-1931. One hastens to point out, as did Sterne, that dynamically a sudden change of such a kind is very unlikely. The two stars would scarcely, in the course of a day or two, increase their speed of mutual revolution and then go on at the new rate. However, it is useful to treat them as if they had, which is what Sterne did. Recent observers seem to find the second period more closely approximating their observations. Mason[7] pointed out in 1922 that the period is getting shorter. Incidentally, most minima are observed earlier than the predicted time, which seems to indicate further that the period is decreasing.

4. The so-called "Tikhoff-Nordmann" effect presents another anomaly in the case of Algol. Some twenty or so eclipsing stars show a shift in the time of minimum when observed in different colored light.[8] For most of these stars the primary minimum occurs earlier in yellow than in blue light; but it is the reverse in the case of Algol. The "Demon" star is not the only one for which things are turned around; there are one or two others. Hall[9] believes that his spectrophotometric study of Algol shows no discrepancy in time of minimum in yellow and infra-red light, with an uncertainty of not more than three minutes, and points out that the effect seems to decrease as the observational accuracy increases.

5. The latest discussion of the formulae available is given by Luyten[10] who derives an empirical formula for the heliocentric time of minimum and then shows that whereas dynamical theory predicts terms of long period and probably small amplitude, observations (particularly those discussed by Ferrari[11] and Lyttleton[12]) suggest terms of short period and relatively large amplitude. He concludes bluntly that "we have not advanced one iota in our understanding of the irregularities of

this, the longest known eclipsing binary."[13]

There are, we suppose, two reasons why it is of interest and importance to publish the predicted times of minima of Algol. First, it is always an interesting project to have first-year students of astronomy observe a minimum of Algol as part of their laboratory work. Second, it is an advantage to the research worker who is studying the star to have available such predictions. For both of these purposes, an error of ten minutes in the prediction is not serious, since the student could scarcely tell the difference, observing visually, and since the research worker would be aware of the uncertainties involved and would plan his program to include the minimum by starting possibly a few hours before the time of predicted minimum and continuing for some time after it. But an error of an hour might be serious in the second case, and such errors have been mentioned, we find.

From this examination of the literature, therefore, it would seem to the writer that the most satisfactory procedure at the present time, would be to have one observatory that is well equipped to do so, obtain annually an accurate photographic record (and visual also, if possible) of the time of a minimum of Algol, and thus to establish a satisfactory initial epoch for the following season. Then, by using the mean period only, the predictions could be given to within a few minutes. The sine terms in the various formulae used now are not of appreciable value except when an initial epoch of several years standing is used. Gaposchkin's minimum,[14] observed in December of 1938, was apparently the result of discussion of this very subject at the meeting of the AAVSO at Wellesley College in September, 1938. Using the minimum mentioned above, $5^d\,02^h\,17^m$ and the period of $2^d.867318$ derived by Smart,[15] we obtain the following U.T. of the first minima (geocentric) in January of 1942 and 1943:

1942, Jan. $2^d\,1^h.8$; 1943, Jan. $1^d\,5^h.4$.

It seems important to the author that such a program should be the definite responsibility of one observatory, carried on under consistent conditions so far as possible. A long series of observations with the great advantage of homogeneity might prove more useful in determining the fundamental orbits involved than is at present recognized.

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[2] *E.g.*, Prager, R., *Katalog und Ephemeriden Veränderlichen Sterne*, **152**, 1935.
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[9] *Ap. J.*, **90**, 463-464, 1939.
[10] *Z. f. Ap.*, **15**, 97, 1938.

[11] *A.N.*, 253, 225, 1934.
[12] *M.N.*, **95**, 42, 1934.
[13] *Ibid.*, p. 106.
[14] *Pop. Astr.*, **47**, 51, 1939.
[15] *M.N.*, **97**, 402, 1937.

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The Limiting Magnitudes of Photographic Telescopes

By FRED L. WHIPPLE and PEARL J. RUBENSTEIN

The purpose of this paper is to present a practical working formula for the prediction of the limiting stellar magnitudes attainable with photographic telescopes. No high order of accuracy is to be expected because there are many variables involved, and because the "limiting magnitude" itself depends upon the method of measurement. The general problem has been investigated by Hubble[1] and by Ross.[2]

We deal with the single case in which the optimum maximum exposure is made, when the light of the night sky produces a photographic density of from 0.5 to 0.9 on a fast blue sensitive emulsion developed to a gamma of the order of unity. The exposure time necessary to produce this result is assumed not to enter the problem and will depend for a given sky brightness only upon the focal ratio and efficiency of the telescope and upon the speed of the emulsion used.

We adopt as a working hypothesis Hubble's result that a faint image is just detectable when the product of the image diameter, d, and the ratio of the surface brightness of the stellar image to that of the sky is a constant. Hubble's result is applied here more generally than is justified by his observations, but the extension appears not to introduce serious errors.

The diameter of the image as ordinarily measured is assumed to be the sum of three parts: (a) a distance slightly less than that defined by the first minimum of the theoretical diffraction pattern, $8''.1/A$ (aperture in inches); (b) the diameter of the atmosphere seeing disc, s''; (c) the turbidity disc of the photographic emulsion, assumed to be 0.02 mm. In case the optical system of the telescope is imperfect, an additional term may be added.

Let us consider a series of telescopes of linear aperture A_i, focal length F_i, and optical transmission T_i that produce images of diameter d_i. The light from a star of apparent luminosity $L(\text{star})$ will produce an image with an average surface brightness proportional to $A_i^2\, T_i\, L(\text{star})/d_i^2$. Under the same conditions, the night sky of lumin-

[1] *Ap. J.*, **76**, 106, 1932.
[2] *Ap. J.*, **88**, 548, 1938.

osity $L(\text{sky})$ per square second of arc contributes a surface brightness on the emulsion proportional to $(A_i/F_i)^2\ T_i\ L(\text{sky})$. When these proportionalities are substituted into the adopted relation for the limiting detectable image, the following equation results:

$$d_i\ L(\text{star})/L(\text{sky})\ (F_i/d_i)^2 = \text{constant}. \tag{1}$$

If we now transform to a magnitude scale in which m_L is the limiting magnitude of a just-detectable stellar image, and m_s is the brightness of the night sky in magnitudes per square second of arc, and if the subscripts i are dropped, Equation (1) becomes:

$$m_L = m_s + \log F - 2.5\ d + \text{constant}. \tag{2}$$

Equation (2) has an exceedingly simple form for the solution of the complicated photographic, optical, and physiological problem. It is justified not by its derivation but by its dependability in application.

For the brightness of the night sky the photographic magnitude $m_s = 22.0$ mag. $(\text{sec arc})^{-2}$ was adopted from the observations by Elvey and Roach[3] and Jessie Rudnick.[4] No effect of atmospheric absorption should enter the calculation of limiting magnitudes, because the absorption should be practically the same for both the stellar and night-sky radiations.

Observed values for the limiting magnitudes of telescopes are necessary for the evaluation of the constant term in Equation (2), and for confirmation of the form of the equation. In Table 1 are contained the observed values of the limiting magnitudes of various telescopes. The apertures, observatories, focal lengths, measured diameters of images, and limiting photographic magnitudes are given in the first to fifth

TABLE 1

CALCULATED AND OBSERVED LIMITING MAGNITUDES

A (inches)	Observatory	F (inches)	d (cm $\times 10^3$)	m_L (obs.)	m_L (calc.)	$O-C$ m
100	Mt. Wilson (rfl.)	500	8.6*	22.2	22.1	+0.1
61	Harvard (rfl.)	160†	9.0	19.5	19.6	−0.1
60	Mt. Wilson (rfl.)	300	5.0	21.1	21.6	−0.5
36	Lick (rfl.)	209	5.0	20.3	20.8	−0.5
24	Yerkes (rfl.)	93	3.5	19.3	19.4	−0.1
16	Har. MC	83	6.0	18.4	18.6	−0.2
8	Har. IR	50	5.0	17.8**	17.7	+0.1
4	Har. RL	28	3.5	16.8**	16.8	0.0
3	Har. RH	21	3.9	16.2††	16.0	+0.2
1.5	Har. AI	6	3.0	13.8§	13.6	+0.2
1.5	Har. AC	13	11.0‡	14.0§	13.9	+0.1

* Diameter calculated by Eq. (3), $s = 1''$.
† With reducing lens.
** 60-min. limit increased by $1^M.0$.
†† 75-min. limit increased by $0^M.8$.
§ Limits found by comparison with N. Polar Sequence.
‡ In center of field. Lens is corrected to produce best images at a distance from plate center.

[3] *Ap. J.*, **85**, 213, 1937.
[4] *Ap. J.*, **87**, 584, 1938.

columns, respectively. For Harvard telescopes the limits were generally obtained by star counts; exceptions are noted at the bottom of the table. When optimum exposures were not available, a suitable correction was made to reduce to the limit. The image diameters are the means of measures along the short and long axes of the images where trailing has occurred. Measures for the Mount Wilson, Lick, and Yerkes reflectors are taken from the paper by Ross,[2] and from unpublished material kindly given to the author by Dr. Edwin P. Hubble.

A least-squares solution to determine the constant and the coefficient of log d in Equation (2) was made from the material of Table 1 (except for the 61-inch reflector at Harvard and the 36-inch reflector at Lick). The coefficient of log d in Equation (2) was confirmed within a few hundredths of a magnitude. The numerical equation for the limiting photographic magnitudes becomes:

$$m_L = m_s + 5 \log F - 2.5 \log d - 20.78, \tag{2a}$$

where F and d are expressed in centimeters, and $m_s = 22^{M}.0$. (For F in inches and d in millimeters, the constant term becomes -16.09.)

For prediction, when the diameter d cannot be observed, the following formula may be used:

$$d(\text{cm}) = 0.002 + F(s'' + 20''.6/A) \times 4.84 \times 10^{-6}, \tag{3}$$

where s'' is the seeing disk in seconds, and d, F, and A are expressed in centimeters. The corresponding formula for F and A expressed in inches, and d in millimeters, is

$$d(\text{mm}) = 0.002 + F(s'' + 8''.1/A \times 1.23 \times 10^{-4}. \tag{3a}$$

The formula for d gives values in good agreement with the measured values.

The residuals given in the seventh column of Table 1 show that the limiting magnitudes of the sixth column, as calculated from Equation (2a), are in satisfactory agreement with the measured values. Thus the equation can be used with some security in prediction, particularly for smaller telescopes. The equation is weakest in predicting the change in limiting magnitude with change of image size caused by variations in the seeing for the large reflectors. Ross[2] has discussed this difficulty thoroughly, and for more precise calculations his formulae should be applied.

For general convenience, the theoretical limiting magnitudes for various apertures and focal ratios are given in Table 2. Equations (2a) and (3) were used in the calculations. The seeing was taken to be $s = 3''.0$, a fair value for average conditions at most observatories at low altitudes above sea level. Under the best observing conditions, the assumption that $s = 1''.0$ usually gives values of d from Equation (3) that are in good agreement with observation. For refracting telescopes the actual image diameter is often increased by chromatic and spherical aberrations. An allowance for this effect must be made with regard to

individual cases. The value of $m_s = 22.0$ should be reduced for observatories located near large cities where the sky illumination is increased by artificial sources.

TABLE 2

CALCULATED LIMITING MAGNITUDES

		$F/A = 3$		$F/A = 5$		$F/A = 7$	
A (cm)	A (inches)	d (mm)	m_L	d (mm)	m_L	d (mm)	m_L
1.0	0.4	0.023	10.20	0.026	11.18	0.028	11.84
2.5	1.0	.024	12.15	.027	13.12	.030	13.74
5.0	2.0	.025	13.61	.029	14.55	.032	15.18
7.5	3.0	.026	14.44	.031	15.36	.035	15.96
10.0	3.9	.027	15.03	.032	15.96	.037	16.51
15.0	5.9	.030	15.80	.036	16.71	.042	17.27
20.0	7.9	.032	16.35	.040	17.21	.047	17.77
25.0	9.8	.034	16.77	.043	17.62	.052	18.15
30.0	11.8	.036	17.10	.047	17.92	.058	18.42
40.0	15.7	.041	17.58	.054	18.39	.068	18.88
50.0	19.7	.045	17.96	.061	18.75	.078	19.21
60.0	23.6	.049	18.28	.069	19.01	.088	19.48
75.0	29.5	.056	18.61	.080	19.33	.103	19.79
90.0	35.4	.062	18.90	.091	19.59	.119	20.04
100.0	39.4	.067	19.05	.098	19.74	.129	20.17

Attention is again called to the fact that Equation (3a) is intended to apply only for the optimum exposure, sufficiently long to register the night sky light strongly on the emulsion. The optimum limiting magnitude may be increased in practice by the use of a photographic emulsion with less turbidity developed to a higher gamma.

Extrapolation to a Red-Magnitude System: No precise measures of limiting magnitudes are available for a determination of the equations in a red-magnitude system. The value of m_s should be decreased by an amount of the order of $0^M.8$, according to Ross' adopted value of the color index of the night sky. The presence of the strong night-sky line, λ 5577, produces a considerable dependence of m_s upon the exact wave-length region covered by the system. The theoretical image diameter, d, should be increased because of emulsion turbidity (the constant 0.02 mm increases to perhaps 0.03 mm) and because of increase in the size of the diffraction image proportionally to the effective wave-length. (In equation 3a the term $8''.1/A$ should increase to perhaps $10''/A$). The effect of seeing is about the same in the red region of the spectrum, and the contrast of a modern fast red-sensitive emulsion is similar to that of a fast blue-sentitive emulsion, so that the other constants of equation (2a) and (3a) probably should not change markedly.

HARVARD COLLEGE OBSERVATORY, JANUARY 3, 1941.

The Longitude of the Goodsell Observatory*

By MERTEN HASSE

A determination of the longitude difference between two stations involves a comparison of the local sidereal times of the two stations at a given instant. Formerly, the sidereal time was determined at one station and then a chronometer was transported from this station to the other station; or telegraphic signals were exchanged on a simultaneous observing schedule. Modern procedure utilizes radio time signals for the comparison.

The Greenwich (zero) meridian is the primary reference line for longitude, although there are several observatories throughout the world whose meridians are used as secondary references. The United States Naval Observatory at Washington is often taken as such in this country. The time signals as determined by this observatory are transmitted hourly by radio on several high frequencies over station NPG (formerly also over station NAA). Reception of these signals is consistently good throughout the western hemisphere.

The first determination of the longitude of the Goodsell Observatory was made by Professor W. W. Payne in September, 1880. The method used was the exchange of telegraphic signals with a station of the United States Deputy Surveyor in St. Paul, Minnesota. This determination is mainly of historic interest, since precision in observation and instrumental equipment was largely lacking. However, Professor H. C. Wilson of the Goodsell Observatory, who analyzed the results in *Publications of Goodsell Observatory, No. II*, regarded them as good, considering the equipment and methods used. A second and more nearly precise determination was made by Professor Wilson during the months of October and November, 1889. Two additional determinations have been carried through by the writer, one in 1927-28 and another in 1940.

The general procedure in the last three programs was the determination of the local sidereal time by means of "time sets" and the comparison of this local time with the Washington sidereal time at the same instant. Professor Wilson used the exchange of telegraphic signals. For the last two determinations the radio signals from the U.S. Naval radio stations were received and recorded.

Several correction factors must be applied to the recorded observations for determining sidereal time to make them usable. These fall into three main classes: instrumental factors, depending on the orientation of the observing instrument; electrical lag in the electromagnetic receiving and recording apparatus; and a "personal equation" arising

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from the judgment of the observer. This last factor is eliminated in the newest photographic method which is now employed in some observatories. The reduction of the "time sets" follows the standard form, $\Delta\theta = aA + bB + cC$, which may be found in any standard book on Practical Astronomy, where $\Delta\theta$ is the required clock correction.

Practically the same instruments were used in the last three determinations at Goodsell. The transit instrument is a Repsold Meridian Circle installed in 1887. Wilson used Howard Clock No. 195 as his sidereal timepiece. In the 1927-28 program, Riefler Clock No. 227 was used, and, in 1940, Howard Clock No. 242, running on Central Standard Time was set by radio signals. The chronograph is by Alvan Clark and the personal equation machine is by Max E. Kahler. The radio receiving set used in 1927-29 was constructed by the writer. A RCA-Victor all-wave receiver was used in 1940.

The results of the determinations of 1889, 1927-28, and 1940 are in fair agreement. Variations of the separate results are systematic and seasonal and are due, apparently, to temperature effects.

Professor Wilson in his determination used the average of observations on three nights, each employing 14 to 16 "time stars." In the program of 1927-28, extending from December to May, there were eleven separate sets of observations, with from 9 to 15 time stars. There were seven sets of observations in the July, 1940, determination, with 10 to 14 time stars.

RESULTS

Year of Determination	Longitude Difference (Goodsell Observatory—U.S. Naval Observatory)
1889	$1^h\,4^m\,20^s.14 \pm 0^s.03$
1927-28	$1^h\,4^m\,20^s.01 \pm 0^s.03$
1940	$1^h\,4^m\,20^s.04 \pm 0^s.03$

Assigning equal weight to the three determinations, the resulting mean value for the difference in longitude between the Goodsell Observatory (meridian circle pier) and the U.S. Naval Observatory is

$$1^h\,4^m\,20^s.06 \pm 0^s.03$$

The commonly accepted value for the longitude of the U.S. Naval Observatory west of Greenwich is

$$5^h\,8^m\,15^s.78$$

This value is subject to revision when the results of the 1926 and 1933 world longitude programs have been reduced and accepted. Adding this amount to the above value of

$$1^h\,4^m\,20^s.06 \pm 0^s.03$$

gives as the longitude of the Goodsell Observatory west of Greenwich

$$\mathbf{6^h\,12^m\,35^s.84 \pm 0^s.03}$$

ABERDEEN, SOUTH DAKOTA, AUGUST 1, 1941.

Variability of the Be Star Chi Ophiuchi

By JOSEPH ASHBROOK

The spectrum of χ Ophiuchi is characterized by emission lines of hydrogen superimposed on diffuse absorption lines. C. H. Cleminshaw[1] has studied the extensive spectrographic material accumulated at Ann Arbor from 1913 to 1934. He found the radial velocity from the hydrogen lines to vary with the relative intensity of the red and violet emission edges, in a period roughly estimated at ten years. Superimposed on this slow velocity variation there appear to be more rapid and seemingly irregular changes. No appreciable variation in the total intensity of the hydrogen emission was noted, in contrast to γ Cassiopeiae.

The visual magnitude of χ Ophiuchi is 4.85, according to the Revised Harvard Photometry. However, visual estimates of the brightness of the star made by the author show that it is at present half a magnitude brighter. These observations were made by the Pickering interpolation method, using an opera glass. The magnitudes of the comparison stars, ϕ, ψ, ω Ophiuchi, θ, 48 Librae, ν, 24 Scorpii, were taken from the Revised Harvard Photometry.

J.D. 2429...	Mag.	J.D. 2430...	Mag.
747.8	4.36	122.8	4.32
756.8	4.40	134.6	4.42
2430...		139.7	4.35
117.8	4.43	156.6	4.33
118.7	4.38	164.7	4.28
119.8	4.40	188.6	4.24
		196.6	4.28

Confirmation of the increased brightness is given by additional estimates by Professors J. J. Nassau and S. W. McCuskey of the Warner and Swasey Observatory, and by Dr. E. C. Cherrington of the Perkins Observatory. The comparison stars were ν Scorpii, ϕ and ψ Ophiuchi: a field glass was used.

J.D. 2430...	Mag.	Observer
118.7	4.48	S. W. McC.
118.7	4.33	E. C. C.
118.7	4.50	J. J. N.
119.8	4.30	J. J. N.
122.8	4.44	J. J. N.

Furthermore, on two plates taken June 29, 1941, with the 3-inch Ross Astrograph of this Observatory, χ Ophiuchi appears equal in brightness to ν Scorpii, whence its photographic magnitude was 4.1. Assuming the visual magnitude 4.3 on that date, the resulting color index is $-0^{M}.2$.

From these observations it appears that χ Ophiuchi has for over a year been half a magnitude brighter than when the Harvard photometric measures were made at the end of the last century. As the bright-

ness has been unchanged during the past year, the light variations are slow.

According to Mr. Leon Campbell,[2] the Harvard photometric measures suggest an increase in brightness from 1880 to 1890. The observed magnitudes of the star given in *H. A.* **14**, **24**, **44**, and **46** are 5.03, 5.11, 4.72, and 4.54, respectively. The internal agreement of the Harvard measure in each volume is close.

χ Ophiuchi had been earlier suspected of variability by Gould[3] at Cordoba, on the basis of discordances among the magnitudes estimated for the *Uranometria Argentina,* and because of the different magnitudes assigned by Argelander, Heis, and Yarnall. However Sawyer[4] showed that Gould's suspected variable stars were in general constant in brightness; the twelve observations of Sawyer from 1882 to 1892 ranged between $4^{M}.6$ and $5^{M}.0$, which he did not consider proof of variability. Unfortunately the individual observations were not published.

It should be pointed out that naked-eye stars which undergo slight gradual changes in brightness over the course of years would be overlooked by the ordinary techniques for the discovery of variable stars. The Be light-variables γ Cassiopeiae and X Persei are examples. Therefore, a systematic patrol of the naked-eye Be stars[5] by visual estimates offers the possibility of discovery of additional variable stars of this type.

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The People's Observatory of the Buhl Planetarium and Institute of Popular Science

By WILLIAM ALLISON

The People's Observatory of the Buhl Planetarium and Institute of Popular Science, constructed and equipped at a cost of $30,000, is unusual for its type of telescope and for its purpose.

The Planetarium's observatory is equipped with a siderostat telescope —a machine which holds a star or planet in a stationary position while the observer is looking at it. There is only one other telescope of this type in America, and that in a research observatory. The Planetarium's siderostat telescope is believed to be the only one in the world especially

built for the viewing of celestial objects by the general public.

The Planetarium's observatory was planned for the public's enjoyment—not for the research work of the astronomer. The siderostat telescope makes it possible to look at a star or planet without the neck-bending which goes with looking through an ordinary telescope. The siderostat telescope automatically follows a star or planet across the sky, so that the observer need not make adjustments while he is looking. The Planetarium's observatory is divided into two rooms—one kept at the temperature of the outside night air, and the other room, in which the spectators stand, kept at a comfortable 72 degrees. Further, the Planetarium's telescope "talks"—that is, at the press of a button the Planetarium's sound system brings into the observatory a voice which tells the spectator the story of the star or planet or comet he is observing.

The Planetarium's siderostat telescope was built by the Gaertner Scientific Corporation of Chicago. Designers spent five months planning the machine. Two years of work went into its construction. Each of its thousands of parts was especially designed and handmade.

The idea of the siderostat telescope was first proposed some eighty years ago by the noted French scientist, Leon Foucault. A Foucault pendulum—the device which demonstrates the Earth's rotation on its axis—is in the main gallery of the Buhl Planetarium.

In the Planetarium's siderostat telescope, the magnifying apparatus—the 12-foot horizontal telescope tube, with large objective lens at one end and the small eyepiece at the other—never moves. The objective lens in the Planetarium telescope is ten inches in diameter, and is made up of two pieces of fine astronomical glass from one of the last shipments of astronomical glass to leave Europe. It was ground and polished in America. The telescope is equipped with six eyepieces, which produce six different degrees of magnification, ranging from 65 power to 490 power. Each of the eyepieces has different uses. The 490 power might be used, for example, in viewing comets so faint and distant that they are invisible to the naked eye. The 65 power eyepiece might be used for looking at Saturn or Jupiter.

The steel tube serves only to keep out stray light which would spoil the imaged formed, and to provide support for the lens system.

The Planetarium's siderostat telescope never points toward the sky. Instead, it points at a mirror which does the work of "star-catching." This mirror does the moving, catching the light of a star and reflecting it into the telescope—bending starlight around a corner, so to speak.

The complex machinery which moves the mirror, although it weighs hundreds of pounds, is as delicate as a fine watch, and was built to jewel-like precision.

The mirror, of pyrex glass, is 18 inches in diameter and two and three-quarter inches thick. After the disc's surface was polished to a flatness perfect to within 1/400,000th of an inch, the disc was placed in a vacuum chamber. Then, aluminum, in vapor form, was introduced

into the chamber where it condensed on the glass. This film on the mirror—unlike the coating on the back of an ordinary mirror—is on its front surface.

The mirror is held in a gear apparatus which can move it to the east, west, north, or south, so that it may catch any portion of the sky.

Nine electric motors power the mirror control apparatus. So delicately balanced is this machinery—it contains 100 ball bearings—that the largest of the motors is only 1/20th of a horsepower, and most are much less powerful than that.

This mirror-driving apparatus is controlled from a dial panel at which the observer stands while looking through the telescope at a star or planet. The gearing apparatus may be set to follow automatically the movement of the celestial object being observed.

But more than that, this telescope automatically finds stars. That is, it eliminates the need for the observer to hunt around in the sky—which is more difficult than would seem—to locate the star he wants to look at. Instead, the observer determines from an astronomical guidebook the celestial latitude and longitude of the object he is interested in, sets the controls for that location and starts the mirror moving, and, when the mirror stops, finds the image of the star he is seeking in the eyepiece. Then, a press on a button will make the mirror automatically follow the star's movements.

With ordinary telescopes, the observer must twist his neck to look into the eyepiece. More, he must move his body to follow the telescope's movement as it follows the star or planet across the sky. The observer at the Buhl Planetarium telescope stands or sits in a normal position and looks through the always-horizontal apparatus. The mirror does all necessary adjusting.

There is no discomfort from cold while looking through the Buhl Planetarium's siderostat telescope. In the regular observatory the observer must be in a room which has the same temperature as the outside air. This makes for discomfort, especially on the cold, winter nights when conditions for looking at the stars are often at their best. For if an observatory were heated, the wavering of the warm air moving upward would blur the image of a celestial object. But the Buhl Planetarium's observatory has two rooms, with the objective lens and mirror in the room open to the night air, and the eyepiece in a room kept at a comfortable temperature. A glass partition separates the two rooms, so that visitors may see the machinery in motion. Covering the outside-temperature room in daylight hours is a sliding roof.

All controls for the telescope are in the observer's room. There, on a panel adjoining the eyepiece, are the switches and buttons which move the mirror.

The entire machine weighs one and one-half tons. Its motors use standard 110 volt electricity, as well as 55 volt and 24 volt alternating current.

The People's Observatory of the Buhl Planetarium will be open to persons who attend the sky shows.

NOVEMBER 8, 1941.

Planetary Phenomena in 1942

[The data which appear in this article are taken chiefly from *The American Ephemeris and Nautical Almanac*. The times given are usually expressed in Greenwich Civil Time (G.C.T.), sometimes called Universal Time (U.T.). To find the time of a given phenomenon expressed in Eastern Standard Time, it is necessary to subtract five hours from the Greenwich Civil Time; in Central Standard Time, subtract six hours, etc.]

THE PLANETS

The planets, being wanderers, are constantly changing their positions among the stars. This fact accounts for the circumstance that a bright planet may appear in the evening sky for a time and then disappear from the evening sky and, perhaps, appear in the morning sky a short time later. The wanderings of the planets, however, are in no sense haphazard, but take place according to well-defined and well-understand laws. It is a source of satisfaction to be able to recognize the naked-eye planets as they put in their appearance from time to time. To one sufficiently familiar with the brightness of the several planets, their appearance will usually furnish a clue to their identity. However, this is not an infallible guide because Mars, for instance, at its brightest may be as bright as Jupiter and at its faintest, as faint as Saturn. The color may afford an indication when the brightness leads to uncertainty. But the best clue as to the particular planet that may be in view is its position in relation to the sun at the given time. If one happens to have a copy of *The American Ephemeris and Nautical Almanac* at hand, a little study of it will reveal the situation as to relative positions at any time. Since most persons do not have access to this volume we shall tabulate here the necessary data for the first of each month throughout the year.

The positions of bodies in the sky are denoted by two quantities called *Right Ascension*, usually indicated by the Greek letter alpha (α), and *Declination*, usually indicated by the Greek letter delta (δ). These quantities are to be interpreted somewhat as longitude and latitude on the earth's surface, in that α furnishes the distance an object is from a certain fixed circle, this distance being measured eastward through a complete circle, that is through 360 degrees or 24 hours; δ furnishes the distance north or south of the celestial equator and is usually expressed in degrees. Obviously, δ cannot exceed 90° numerically.

A few words of explanation of the tabulation on page 35 and some suggestions as to how it may be used may be helpful. First it is to be noted that all the α-quantities are without sign. This means that they are all measured in the same direction. The progressive change in α is most clearly shown in the data under Sun. The α increases continuously and, when it reaches 24, it starts again at 0 and runs through another cycle. The signs used in connection with δ show that sometimes these objects are north of the celestial equator and sometimes south of it. By agreement the plus sign indicates *north of*, and the minus sign, *south of*.

RIGHT ASCENSIONS AND DECLINATIONS OF THE SUN AND BRIGHTER PLANETS IN 1942

		—Sun—	—Mercury—	—Venus—	—Mars—	—Jupiter—	—Saturn—
Jan. 1	α	$18^h\ 43^m.3$	$19^h\ 9^m.6$	$21^h\ 23^m.1$	$1^h\ 30^m.9$	$4^h\ 48^m.4$	$3^h\ 21^m.1$
	δ	$-24°\ 4'.3$	$-24°\ 33'.7$	$-14°\ 52'.3$	$+10°\ 20'.5$	$+21°\ 50'.3$	$+16°\ 7'.6$
Feb. 1	α	$20^h\ 55^m.8$	$21^h\ 54^m.4$	$20^h\ 58^m.6$	$2^h\ 30^m.5$	$4^h\ 39^m.8$	$3^h\ 19^m.4$
	δ	$-17°\ 20'.2$	$-10°\ 50'.5$	$-\ 9°\ 30'.0$	$+16°\ 6'.6$	$+21°\ 41'.1$	$+16°\ 10'.0$
Mar. 1	α	$22^h\ 45^m.3$	$21^h\ 3^m.8$	$20^h\ 27^m.4$	$3^h\ 34^m.5$	$4^h\ 43^m.5$	$3^h\ 23^m.9$
	δ	$-\ 7°\ 54'.4$	$-16°\ 0'.0$	$-12°\ 18'.0$	$+20°\ 40'.5$	$+21°\ 53'.8$	$+16°\ 35'.2$
Apr. 1	α	$0^h\ 39^m.1$	$23^h\ 36^m.4$	$21^h\ 46^m.3$	$4^h\ 52^m.8$	$4^h\ 59^m.0$	$3^h\ 34^m.6$
	δ	$+\ 4°\ 12'.6$	$-\ 5°\ 7'.2$	$-11°\ 10'.9$	$+24°\ 0'.2$	$+22°\ 24'.7$	$+17°\ 20'.9$
May 1	α	$2^h\ 30^m.3$	$3^h\ 16^m.7$	$23^h\ 41^m.3$	$6^h\ 12^m.7$	$5^h\ 22^m.1$	$3^h\ 48^m.8$
	δ	$+14°\ 48'.8$	$+19°\ 31'.4$	$-\ 3°\ 0'.0$	$+24°\ 50'.3$	$+22°\ 56'.1$	$+18°\ 12'.4$
June 1	α	$4^h\ 32^m.9$	$5^h\ 41^m.0$	$1^h\ 50^m.3$	$7^h\ 35^m.5$	$5^h\ 50^m.8$	$4^h\ 5^m.2$
	δ	$+21°\ 56'.1$	$+23°\ 19'.7$	$+\ 9°\ 3'.8$	$+23°\ 0'.0$	$+23°\ 15'.8$	$+19°\ 3'.2$
July 1	α	$6^h\ 37^m.1$	$5^h\ 11^m.9$	$4^h\ 7^m.8$	$8^h\ 52^m.9$	$6^h\ 20^m.4$	$4^h\ 20^m.7$
	δ	$+23°\ 10'.2$	$+19°\ 2'.6$	$+19°\ 8'.0$	$+18°\ 49'.6$	$+23°\ 14'.9$	$+19°\ 43'.3$
Aug. 1	α	$8^h\ 42^m.1$	$8^h\ 34^m.9$	$6^h\ 45^m.5$	$10^h\ 9^m.1$	$6^h\ 50^m.4$	$4^h\ 34^m.3$
	δ	$+18°\ 14'.5$	$+20°\ 20'.8$	$+22°\ 33'.2$	$+12°\ 34'.9$	$+22°\ 52'.4$	$+20°\ 11'.4$
Sept. 1	α	$10^h\ 38^m.4$	$12^h\ 2^m.5$	$9^h\ 23^m.5$	$11^h\ 22^m.6$	$7^h\ 17^m.1$	$4^h\ 43^m.0$
	δ	$+\ 8°\ 35'.9$	$-\ 0°\ 53'.7$	$+16°\ 12'.0$	$+\ 5°\ 2'.2$	$+22°\ 14'.8$	$+20°\ 25'.0$
Oct. 1	α	$12^h\ 26^m.4$	$13^h\ 29^m.7$	$11^h\ 45^m.0$	$12^h\ 33^m.6$	$7^h\ 36^m.9$	$4^h\ 45^m.2$
	δ	$-\ 2°\ 51'.1$	$-13°\ 21'.3$	$+\ 3°\ 12'.5$	$-\ 2°\ 50'.0$	$+21°\ 37'.0$	$+20°\ 24'.9$
Nov. 1	α	$14^h\ 22^m.3$	$13^h\ 20^m.2$	$14^h\ 8^m.6$	$13^h\ 49^m.9$	$7^h\ 47^m.9$	$4^h\ 40^m.3$
	δ	$-14°\ 9'.4$	$-\ 6°\ 10'.2$	$-11°\ 52'.4$	$-10°\ 47'.7$	$+21°\ 14'.2$	$+20°\ 12'.9$
Dec. 1	α	$16^h\ 25^m.6$	$16^h\ 24^m.9$	$16^h\ 40^m.8$	$15^h\ 9^m.6$	$7^h\ 46^m.6$	$4^h\ 30^m.9$
	δ	$-21°\ 40'.3$	$-22°\ 26'.4$	$-22°\ 12'.4$	$-17°\ 28'.6$	$+21°\ 22'.3$	$+19°\ 53'.9$

Since α increases toward the east, the larger the value of α the farther east the object. We can readily see from the table that on February 1 Mercury is almost exactly one hour east of the sun, and that Venus is only a few minutes east of the sun. At first sight the position of Mars relative to the sun on February 1 might not be so easily discovered. For this purpose we add 24 hours to the value given for α and for the moment think of the α for Mars on February 1 as $26^h\ 30^m.5$. Now it is evident at once that Mars is between five and six hours east of the sun.

If an object is east of the sun, a moment's thought will lead to the conclusion that it will set after sunset, and if west of the sun it will rise before sunrise. In general, this conclusion is correct, but it is modified somewhat by the relative values of δ and the position on the earth from which it is observed. For example, Mercury is one hour east of the sun on February 1, and it is also nearly seven degrees north of the sun. This will cause it to set more than one hour after the sun if it is observed from the northern hemisphere. If all observations were made from points on the equator, the relative values of α would tell the correct story. A little study of a celestial globe will make clear the principles involved here.

The use of this table then might be summarized as follows: subtract the α given for the sun from the α given for the planet, adding 24 hours when necessary to avoid differences exceeding twelve hours; if the resulting difference is positive, the planet is east of the sun; if it is negative, the planet is west of the sun. In the former case we should be dealing with an evening star, in the latter, a morning star.

Illustrating a further use of the table let us suppose that on June 1, before sunrise, an observer is in a location from which he has an unobstructed horizon. If the sky is clear his attention will doubtless be attracted by an especially brilliant object in the eastern sky. Knowing that there is no star as bright as this object, he concludes that it is a planet. Then the question arises as to which planet. A study of the table for this date shows that Venus is between two and three hours west of the sun and conseqently will rise before the sun. If his observations enable him to note the point on the horizon at which the object first appeared and if he finds it to be some twelve degrees south of the point of sunrise, his identification would be practically complete, and his conclusion that he is looking at the planet Venus would be verified.

Other applications of the table will appear to those who study it sufficiently to become familiar with it and to understand it.

Additional aspects and configurations of the planets might be pointed out, but these will be mentioned month by month in "Planet Notes," one month in advance of their occurrence. Also the predictions of occultations of stars by the moon will be listed for three regions of the United States from month to month.

Eclipses

An eclipse, whether of the sun or of the moon, always arouses interest. Because eclipses of the moon sometimes occur late at night or even while the moon is below the horizon for a given observer, and because the total eclipses of the sun are visible from very limited regions on the earth, the general impression is that eclipses are only of rare occurrence. This is hardly the case. The positions and motions of the earth and the moon relative to the sun are such that each year at least two eclipses must occur and as many as seven may occur. When only two occur, they are necessarily both of the sun. The maximum number may consist either of five of the sun and two of the moon or of four of the sun and

three of the moon.

In the year 1942 there will be three solar eclipses and two lunar eclipses. The information which follows concerning these eclipses is taken almost entirely from *The American Ephemeris and Nautical Almanac.*

I. A total eclipse of the moon, March 2-3, 1942, visible partly at Washington; the beginning visible generally in Asia except the extreme eastern part, the Indian Ocean, Europe, Africa, the Atlantic Ocean, eastern and central South America, and the extreme northeastern part of North America; the ending visible generally in western Asia, Europe, Africa, the western part of the Indian Ocean, North America except the extreme northwestern part, the Atlantic Ocean, South America, and the eastern part of the Pacific Ocean.

CIRCUMSTANCES OF THE ECLIPSE

	G.C.T. d h m
Moon enters penumbra	March 2 21 27.6
Moon enters umbra	2 22 31.3
Total eclipse begins	2 23 33.2
Middle of the eclipse	3 0 21.5
Total eclipse ends	3 1 9.8
Moon leaves umbra	3 2 11.5
Moon leaves penumbra	3 3 15.0

Magnitude of the eclipse = 1.567 (Moon's diameter = 1.0)

II. A partial eclipse of the sun, March 16-17, 1942, invisible at Washington.

CIRCUMSTANCES OF THE ECLIPSE

	G.C.T. d h m	Longitude ° ′	Latitude ° ′
Eclipse begins	March 16 21 44.5	—121 51	—67 51
Greatest eclipse	16 23 36.7	+ 76 43	—72 16
Eclipse ends	17 1 29.4	+109 7	—32 19

This eclipse is of little interest because of the remote regions from which it will be visible. The only land from which it can be seen is a small section of Antarctica; except for this it will be visible only in the South Pacific.

III. A partial eclipse of the sun, August 12, 1942, invisible at Washington.

CIRCUMSTANCES OF THE ECLIPSE

	G.C.T. d h m	Longitude ° ′	Latitude ° ′
Eclipse begins	August 12 2 8.4	— 89 38	—61 47
Greatest eclipse	12 2 44.8	—100 2	—70 27
Eclipse ends	12 3 20.8	—127 28	—74 46

This, like the one mentioned above, is also of little interest and for the same reason. Moreover, at maximum only a small portion of the sun's disc will be obscured. It is likely that this eclipse will occur without any one becoming aware of it from direct observation.

IV. A total eclipse of the moon, August 26, 1942, visible at Washington; the beginning visible generally in southwestern Asia, the western part of the Indian Ocean, Europe, Africa, the Atlantic Ocean, North America except the northwestern and extreme western part, South America, and the southeastern part of the Pacific Ocean; the ending visible generally in southwestern Europe and part of the British Isles, the western part of Africa, the Atlantic Ocean, North America except the extreme northwestern part, South America, and the eastern

part of the Pacific Ocean.

CIRCUMSTANCES OF THE ECLIPSE

	G.C.T. d h m
Moon enters penumbra	August 26 1 1.7
Moon enters umbra	26 2 0.5
Total eclipse begins	26 3 0.9
Middle of the eclipse	26 3 48.0
Total eclipse ends	26 4 35.0
Moon leaves umbra	26 5 35.3
Moon leaves penumbra	26 6 34.0

Magnitude of the eclipse = 1.541 (Moon's diameter = 1.0)

V. A partial eclipse of the sun, September 10, 1942, invisible at Washington.

CIRCUMSTANCES OF THE ECLIPSE

	G.C.T. d h m	Longitude ° ′	Latitude ° ′
Eclipse begins	September 10 13 57.1	+134 51	+71 0
Greatest eclipse	10 15 39.1	— 50 0	+71 59
Eclipse ends	10 17 21.4	— 12 38	+36 37

In this eclipse approximately one-half of the disc of the sun will be obscured at the time of maximum eclipse.

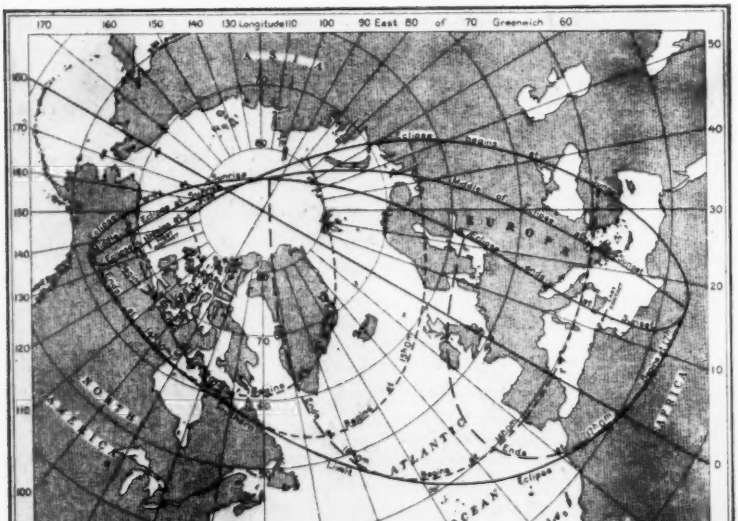

FIGURE 1

From the latitudes and longitudes given above and from the map (Figure 1) taken from *The American Ephemeris*, it is seen that this eclipse is visible in the densely populated area of Eastern Europe and Northern Africa. It therefore will

be taken note of by many persons. However, while it will interest many and possibly alarm some untutored persons, from the scientific point of view it will not be of much significance. Noting the time of beginning and ending will afford a means for verifying the laws upon which the predictions were based, but for investigations into questions concerning the nature of the sun itself a total eclipse is required.

Planet Notes for February, 1942

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from *The American Ephemeris and Nautical Almanac*.

Sun. Apparent positions of the sun for February 1 and February 28, respectively, are: $\alpha = 20^h\,55^m.8$, $\delta = -17°\,20'.1$; $\alpha = 22^h\,41^m.5$, $\delta = -8°\,17'.0$. On February 9, the sun will leave the constellation of Capricornus and enter Aquarius.

Moon. Phenomena of the moon will occur as follows:

		h	m
Full Moon	Feb.	1	9 12
Last Quarter		8	14 52
New Moon		15	10 2
First Quarter		23	3 40
Perigee	Feb.	11	12
Apogee		23	14

Mercury. Mercury will be in inferior conjunction on February 9. Thereafter the planet will be situated in the morning sky but quite inconspicuous due to its nearness to the sun and to its southerly declination.

Venus. Venus will reach inferior conjunction February 2, 17^h. At conjunction, Venus will be 2° to the west of the sun and 7° to the north. The angular diameter of the planet at conjunction will be $1'\,2''$. After conjunction the planet will appear in the morning sky.

Mars. By the end of February Mars will have moved from the constellation Aries into Taurus, and will be situated about 5° southwest of the Pleiades. On February 24, 2^h, Mars will be in conjunction with, and 3° 28′ to the north of Saturn. By the end of February Mars will be distant 1.48 astronomical units from the earth, and its angular diameter will have diminished to 6″.

Jupiter. Jupiter will be an evening object situated about 5° northeast of Aldebaran in the constellation Taurus. Retrograde motion ends on February 5.

Saturn. Saturn will reach eastern quadrature on February 11, near the western boundary of Taurus. The constellation Taurus will constitute a brilliant spectacle during the late winter months, with Mars, Jupiter, and Saturn, within its confines.

Uranus. Also present in the constellation Taurus will be the telescopic planet Uranus. Apparent positions of the planet for February 1 and February 28, respectively, are $\alpha = 3^h\,36^m.3$; $\delta = 19°\,8'.9$; $\alpha = 3^h\,37^m.4$, $\delta = 19°\,13'.1$. The planet will be stationary in right ascension on February 3, about a degree west of the 6.3 magnitude star, 14 Tauri. Mars will be 1° 37′ north of Uranus on March 2.

Neptune. Neptune is still accessible in the evening sky, but is too near the sun for satisfactory observation.

Occultation Predictions for February 1942

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into acount, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Grennwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1942	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
Feb. 3	44 Leo	5.9	0 39.9	..	..	35	1 1.4	..	..	353
4	80 Leo	6.4	5 45.6	—1.9	+0.6	93	6 59.8	—1.4	—1.6	319
5	13 Vir	5.9	6 45.1	—1.2	—1.1	140	7 58.9	—2.0	—0.1	274
5	η Vir	4.0	7 21.1	—2.2	+0.6	84	8 28.7	—1.1	—2.0	330
7	623 B.Vir	6.5	6 37.2	—0.6	—0.8	147	7 37.6	—1.7	+1.2	261
7	95 Vir	5.5	7 45.9	—1.5	+0.4	105	9 1.8	—1.5	—0.6	305
7	κ Vir	4.3	12 29.8	..	..	186	12 45.9	..	..	212
10	90 B.Oph	6.5	8 25.9	—0.5	+0.4	122	9 28.9	—1.2	+1.2	265
12	187 B.Sgr	6.4	11 20.0	—1.5	+2.0	55	12 19.2	—1.2	0.0	306
23	179 B.Tau	6.0	0 3.7	—2.0	—1.7	110	1 19.0	—1.7	+0.8	228
24	318 B.Tau	5.7	0 30.3	—2.0	+2.2	41	1 35.6	—1.7	—3.1	306
25	130 Tau	5.5	0 13.9	—2.3	—2.1	128	1 24.7	—2.2	+1.8	227
26	26 Gem	5.1	3 27.8	..	..	175	3 45.3	..	..	200
27	162 B.Gem	5.6	1 10.7	—2.0	—0.6	111	2 38.2	—2.1	—0.2	266
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Feb. 4	80 Leo	6.4	5 17.4	—1.2	+0.2	116	6 32.9	—1.5	0.0	290
4	89 Leo	5.8	11 12.2	—2.0	0.0	63	11 58.2	—0.3	—3.2	345
5	13 Vir	5.9	6 35.2	..	..	176	7 11.8	..	..	234
5	η Vir	4.0	6 48.0	—1.4	+0.1	114	8 5.3	—1.6	—0.4	298
7	623 B.Vir	6.5	6 45.8	..	..	197	6 52.2	..	..	207
7	95 Vir	5.5	7 26.7	—0.6	—0.2	133	8 33.1	—1.4	+0.8	275
12	187 B.Sgr	6.4	10 56.8	—0.6	+1.6	78	11 58.9	—0.8	+0.7	287
20	389 B.Cet	6.3	22 26.6	..	..	131	23 6.1	..	..	182
22	179 B.Tau	6.0	23 20.8	—2.6	—0.5	106	0 41.6	—1.9	+2.0	223
23	48 Tau	6.4	5 5.0	0.0	—3.0	134	5 48.6	—0.6	+0.6	218
23	318 B.Tau	5.7	23 49.3	—1.7	+3.1	40	1 2.2	—2.6	—1.8	297
24	130 Tau	5.5	23 32.8	—2.4	—1.0	125	0 39.5	—1.7	+3.2	220
27	162 B.Gem	5.6	0 35.8	—1.8	—0.2	117	1 55.5	—2.0	+1.5	250
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
Feb. 4	80 Leo	6.4	4 59.0	—0.3	—0.4	136	5 53.9	—0.6	+1.5	260
4	89 Leo	5.8	10 12.3	—1.9	—0.9	118	11 36.7	—1.8	—1.4	298
5	η Vir	4.0	6 27.2	—0.3	—1.0	148	7 19.5	—1.0	+1.8	255
7	95 Vir	5.5	7 36.9	..	..	198	7 41.0	..	..	203
23	γ Tau	3.9	7 6.7	—0.1	—2.6	127	7 55.7	—0.5	+0.3	226
26	74 B.Gem	6.2	5 0.9	..	..	40	5 51.4	..	..	333
27	162 B.Gem	5.6	0 0.3	—0.6	+0.7	108	1 5.6	—0.7	+1.8	250

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The success of our Society depends very largely upon the energy and good judgment of our regional directors. These men unselfishly give of their time from the desire to see meteoric astronomy prosper and from their personal interest in the work. But circumstances often force some of our best men either to give up their astronomical activities almost entirely or at least turn to other fields than meteors. When this happens it becomes difficult to find another to take the vacant office. These remarks are preliminary to stating that J. Wesley Simpson, who made the record for the A.M.S. in arousing interest when regional director of the Missouri-South Illinois group, is hereby appointed to the same office which includes the region covering Florida, the south half of Georgia, and the West Indies. His address is 921 W. 17th Court, Miami, Florida. We hope to see a quick and immense increase in interest in this region once he has been able to get in touch with our observers and their occasional helpers. Before leaving this subject, may I request other regional directors please to have their reports for 1941 in my hands by February 1. This will save great trouble in making up our annual report. I should also like to ask all our regular members (except regional directors who are exempt due to the expenses they personally incur in their duties) to save us the trouble and expense of mailing bills to them for the $1 annual dues. Promptness in payment would be much appreciated.

Two parties from the A.A.F.I. Philadelphia organized simultaneous observations on the Orionids for 1941 October 25/26. Group 1 at Roxborough had fairly clear skies and Group 2 at Rieglesville had excellent skies (see Table 1). The first consisted of Miss E. Reilly, Miss L. Smith, J. Conners, Fahy, and Eichelberger, and W. H. Haas of my staff. The second consisted of R. Shutts, R. Gorson, J. Metzner, and J. Vroble. A good many bright meteors were seen, the watch corrections were accurately known, and their plans had been carefully laid. As a consequence, 13 probable coincidences were computed by W. H. Haas which fall within our limits of acceptance, and 4 which do not. The 13 are in Table 2. Haas used the short graphical method we usually employ for such work. When a height is given without a $\pm$ sign after it, only the altitudes were used, as the point in question on the meteor's path was in or nearly in the plane of the stations, making the intersection of the azimuth lines practically indeterminate. The base line is rather short, only 31′ measured in units of geographical latitude, but practical considerations prevent the use of a longer one as yet. I believe that equally good observations, made at stations say 50′ apart, would greatly lessen the number of abnormally high or low results. However, the two groups are heartily to be congratulated on the excellent showing they have made, due to persevering in this type of work despite several occasions in the past, when coincidences were distressingly few.

While there was no reason to expect many Leonids, still I organized two parties for simultaneous work on November 15/16. One consisting of Dr. T. D. Cope of our Physics Department and myself went to a point north of Downingtown, Pennsylvania, the other party under Dr. Donald MacRae of my staff at the Cook Observatory and having also J. Conners, J. Lauchek, and Miss E. Reilly as assist-

ants, were about 30′ east of us. Details of the few results obtained will be published later, but the general statement can be made that the Leonids as well as the sporadic meteors were very scarce on that night.

TABLE 1

Station and Observer	Date 1941	Began	Ended	Int.	Met.	Rate	F.
Beechwood, Mich., Anderson, P.	Aug. 11	10:10	13:45	150	55	22.0	0.3
	12	10:10	11:40	90	27	18.0	0.8
	18	12:15	14:15	120	33	16.5	0.7
	26	12:25	13:25	60	8	8.0	0.6
	Sept. 17	9:05	10:35	90	15	10.0	0.9
	19	9:25	11:25	120	17	8.5	0.8
	20	13:30	14:30	60	13	13.0	0.6
Des Moines, Iowa, Johnson, M. C.	June 14	14:15	15:15	60	4	4.0	0.5
	15	13:00	15:00	120	7	3.5	0.5
	18	13:00	15:00	120	13	6.5	1.0
	20	13:00	14:00	60	2	2.0	0.9
	21	13:00	15:00	120	19	9.5	0.9
Birmingham, Mich., Borden, W. A.	Sept. 13	9:50	12:00	130	50	23.0	0.4
	14	9:35	12:55	200	60	18.0	1.0
	15	9:35	11:00	85	25	17.6	1.0
	16	14:30	17:25	175	79	17.3	0.8
	17	10:00	11:30	90	31	20.7	1.0
	19	8:25	15:25	295	90	18.3	0.7
	21	10:00	12:15	135	44	19.6	1.0
	22	11:35	12:50	75	24	19.2	1.0
	27	10:50	12:40	110	36	19.7	0.8
Drake, J.	27	10:50	11:35	45	8	10.7	0.7
Borden, W. A.	Oct. 5	10:20	12:20	120	27	13.5	0.4
	7	7:20	12:55	195	37	11.4	0.5
	12	7:30	12:00	132	29	13.2	0.7
	16	13:00	15:05	125	36	17.3	0.4
	Nov. 3	10:00	11:20	80	11	8.2	0.4
	16	11:15	12:15	60	17	17.0	1.0
E. Norwalk, Conn., Martin, H. S.	Aug. 23	11:00	13:00	120	17	8.5	0.8
Washburn Obs., Madison Astr. Soc.	11	9:20	10:20	60	53	..	..
New Orleans, La., Williamson, P. B.	11	9:30	13:30	240	38	..	0.5
	12	12:	13:	60	4	..	..
Hagerstown, Md., Mrs. Hahn, J. A.	12	9:30	12:30	180	42	14.0	0.7
Dallas, Texas, Pietsch, L.	11	10:15	14:40	265	67	15.2	0.9
Gridley, Calif., Johnson, W.	11	8:29	9:59	90	19	12.7	..
Blue Earth, Minn., Pirsig, G.	11	9:10	10:15	65	18	16.7	0.8
Champaign, Ill., Tapscott, C.	Sept. 17	10:15	11:30	75	12	9.6	0.8
	23	10:15	12:01	106	14	7.9	0.9
	Oct. 23	10:55	11:35	40	5	7.5	0.8
	Nov. 15	12:34	14:35	120	10	5.0	0.9
	16	13:15	15:32	137	11	4.8	0.8
Roxborough, Pa., A.A.F.I. (1)	Aug. 16	10:15	13:06	..	47	..	0.8
Rieglesville, Pa., A.A.F.I. (2)	16	10:30	14:15	..	100	..	1.0
Roxborough, Pa., A.A.F.I. (1)	Sept. 20	11:59	14:00	..	24	..	1.0
Rieglesville, Pa., A.A.F.I. (2)	20	10:10	13:35	..	51	..	0.9
Roxborough, Pa., A.A.F.I. (1)	Oct. 25	11:43	14:00	197	34	..	0.9
Rieglesville, Pa., A.A.F.I. (2)	25	11:50	14:05	195	63	..	1.0

TABLE 2

Time h	m	s	S1	S2	M1	M2	Beginning km	Ending km	Remarks
12	5	0	4	8	0	0	62.4	47.5	Orionid?
12	17	28	7	14	1	1	196.0 ± 2.5	158.9 ± 5.3	Orionid
12	30	27	8	22	3	3	173.6 ± 23.5	105.7 ± 11.7	Sporadic
12	35	50	9	23	2	2	108.2 ± 10.0	71.6 ± 5.4	Orionid

Time h	m	s	S1	S2	M1	M2	Beginning km	Ending km	Remarks
12	38	33	10	25	3	2	87.6 ± 8.9	67.0 ± 6.4	Orionid
12	42	52	11	26	2	2	182.0 ± 4.9	176.7 ± 18.8	Orionid?
12	44	22	13	27	4	2	151.7 ± 8.8	141.4 ± 16.5	Orionid
12	54	47	18	33	4	3	99.8 ± 6.2	99.2 ± 13.4	Sporadic?
13	0	54	20	37	2	2	145.8 ± 0.5	80.2 ± 6.2	Sporadic
13	3	46	21	39	3	2	99.8 ± 6.0	104.5 ± 16.7	Sporadic
13	27	33	28	47	1	1	140.5 ± 3.0	88.9	Orionid
13	50	58	32	58	4	3	89.4 ± 1.0	62.6 ± 0.4	Sporadic??
13	55	34	34	61	—1	1	131.7 ± 3.6	110.4 ± 3.0	Orionid*
Average							128.3 ± 6.1	101.1 ± 8.0	

* 3 observers.

CHARLES P. OLIVIER.

Flower Observatory, Upper Darby, Pennsylvania, 1941 December 13.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
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The Great Meteor of 1941 June 28*

By H. H. NININGER
Colorado Museum of Natural History, Denver

ABSTRACT

This is a report of observations by 4 scientists who witnessed the flight of a great meteor as they were returning from the Eighth (Flagstaff, Arizona) Meeting of the Society for Research on Meteorites, on 1941 June 28. Interesting data were recorded by these observers, who were more than 200 miles from the vanishing point of the meteor, and these observations of its appearance are compared with those of individuals who observed the same phenomenon from near-by points.

For many years I have looked forward to the possible good fortune of being a personal witness to a large meteor. Consequently, on the evening of 1941 June 28, when my 3 companions and I were treated to such a sight, I was in a position to make the most of the occasion.

In the course of the past 17 years, I have interviewed thousands of witnesses to such events and have had deeply impressed upon my mind the importance of looking for certain details upon which observers often disagree. The passage of a meteor is so very brief and so totally unexpected, that the average individual,

* [Most meteors—especially *bolides* or *fireballs*—are witnessed, of necessity, by laymen and amateurs. The following detailed account of the observation of a *great* meteor is believed to be almost unique—and it is doubly valuable—as a record of the first-hand impression of such an unusual phenomenon on an experienced meteoriticist.—ED.]

however intelligent, is almost certain to gain incorrect impressions regarding certain matters. The unschooled person is likely to be influenced by fear or superstition and will almost certainly fail to recognize the event as of sufficient importance to warrant any special effort at accuracy. The educated person, on the other hand, will be influenced by an inadequate appreciation of the complex nature of the problems involved. His conception of such phenomena will be based upon a limited study, probably a few textbook descriptions, unless, as is rarely the case, he has read very widely into meteoritical literature. Consequently, he will see only those salient features that the typical textbook account emphasizes.

It is a conservative statement that hundreds of times within the past decade, as I have contemplated the puzzling problems arising from conflicting reports of meteoric phenomena, I have, in my imagination, endeavored to outline a course of action to be followed in the event that I should see a large meteor. I doubt whether, in the course of the last 10 years, there has passed a single day when I have been out in the open country, on which I have not considered the possibility of such an experience and what should be done if such good fortune should be mine. At least twice on the very day on which the subject of this account took place, I had gone over the list of "things to be done"; once, as we were crossing the San Luis Valley, between the New Mexico border and La Veta Pass, and again as we spanned the stretch of open country between Walsenburg and Pueblo, Colorado. Naturally, I should have preferred a daylight fall! But just as hundreds of other ideal days in the open had passed uneventfully, so this one came to a close in the ordinary way.

We were driving north on U.S. Highway 85. Darkness had closed in from the east, allowing the stars to appear faintly overhead. The crescent Moon shone brightly from an elevation of about 20°, midst scattered clouds. Below it, a dark strip of rather heavy cloud stretched from north to south above a narrow zone of fading amber twilight in the upper portion of which Venus, masked by the heavy atmosphere, lost much of her brilliance, but stood out plainly with a strong and somewhat sparkling orange-colored light.

At 8:15 P.M., we were on an open stretch of road about 3 miles south of Larkspur, Colorado, when suddenly my son, Robert, who was at the wheel, exclaimed, "Look! Look!", and nodded toward the west. We all looked in time to see a large, and noticeably brightening, meteor plunge behind the heavy clouds. Orders were given to stop the car and check the time. Before the act of stopping was completed, the meteor emerged from the lower edge of the cloud, appearing surprisingly large, and brilliant beyond all expectations. In its light, Venus, a scant 2° away, faded to obscurity. The movement of the meteor, which had been apparently slow from the first, now seemed slower than ever, so that a whole second elapsed (estimate agreed upon by all the members of the party) during its sub-nimbus course of about 1°. Here the meteor appeared like a large photo-flood electric bulb or, as the other 3 persons in the party agreed, it resembled in color the electric arc produced in the process of welding.

As to the process by which the meteor vanished, I confess I am not clear. The picture in my mind has been, from the first, that of a sudden shrinking to extinction. The others seemed to see the phenomenon shattered into sparks. Of one thing I am sure. The disappearance of the brilliant fireball was sudden, and 3 large orange-colored sparks continued on in divergent courses almost to the horizon, fading into red as they proceeded. After we completed our survey 2 weeks later, I was inclined to the belief that the end took the form of a bursting into sparks, since the other members of our party were in substantial agreement

as to this phase of the phenomenon. Following are some of the questions considered, together with their answers.

First: How did the brightness of the meteor compare with that of the 4½-day-old Moon? Much brighter.

Second: With that of Venus? 6 or 8 times the apparent "area" of Venus, but the meteor was of a very much more intense light than the planet.

Third: How long was the meteor visible (here seconds were counted for comparison)? About 5" or 6", exclusive of the 3 final sparks.

Fourth: Were sparks being discharged before the meteor passed behind the cloud? Yes.

Fifth: Were more than 3 sparks thrown off at the finish of the brilliant phase of the phenomenon? *2* observers were positive that there were; the third one was uncertain. I saw but 3 sparks.

Sixth: What was the shape of the fireball below the cloud where it was best observed? To some, it had a tear-drop shape. Others were uncertain. To me, who definitely looked for this feature, it was circular with a short, sharp, pointed extension rearward. It tended, thus, toward a drop shape. This nucleus had the dazzling, fluid quality of the disk of the Sun and was surrounded by a chromatic envelope in which orange was the only color of which I could be sure.

Seventh: What was the apparent diameter of the fireball at its largest? About one-third the diameter of the full Moon.

Eighth: What was the color of the fireball? Its nuclear color was seen by the others as slightly bluish, "like that of the electric welding flame." This color I failed to see, probably on account of the tinted lenses of my eyeglasses. I wear *A*-shade, Crookes lenses.

Ninth: What was the color of the sparks given off above the cloud? A reddish, flame color.

Tenth: What was the color of the final 3 sparks? Orange, like Venus at her low elevation, in the amber twilight. (Venus was so near that this comparison should have been fairly accurate.)

Eleventh: How did these sparks compare with Venus in apparent size? About the same.

Twelfth: What was the angle of descent of the meteor? About 30° when it was above the cloud; but strikingly more nearly vertical when it emerged below the cloud. All testified that they were astonished both as to the point at which the meteor reappeared and by its almost "vertical" course thereafter. This effect was due, of course, to the tendency of our line of sight to parallel the line of flight of the incandescent body.

Thirteenth: At what elevation was the meteor first noticed? At about the altitude of the Moon.

Fourteenth: Where did the brilliant phase vanish? A scant 2° north of Venus.

Fifteenth: What degree of divergence was there between the final 3 sparks? About 23° between the 2 extreme ones.

Sixteenth: Did any of the 3 sparks reach the horizon? No.

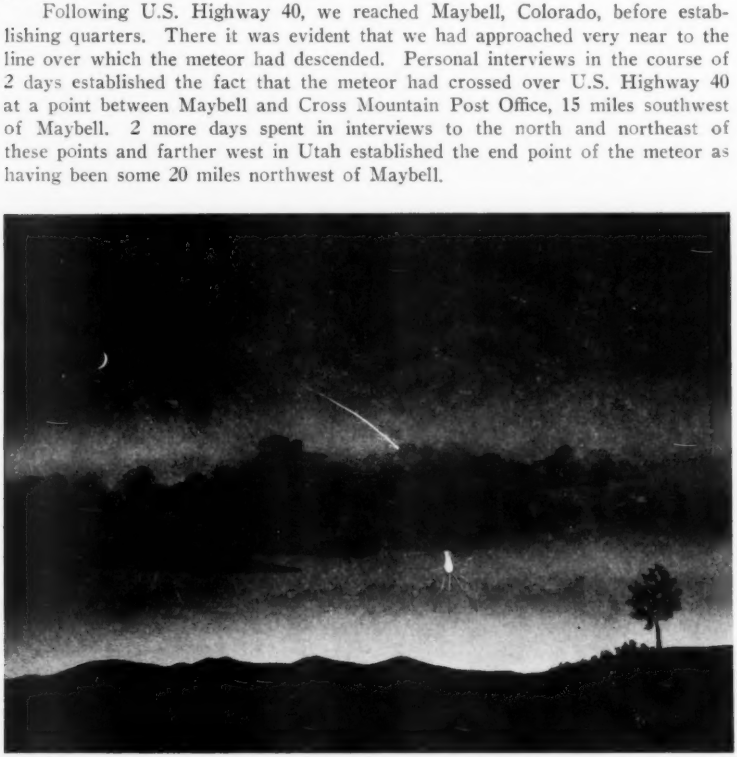
Seventeenth: Was any sound heard in the course of the passage of the meteor? (We were in a moving automobile.)

Eighteenth: Were any detonations heard, subsequent to the passage of the meteor? No.

A rough plotting of our line of observation passed near the northwestern part of Colorado, and within a few days we had reports from various distant points in Colorado and in Wyoming and in northern New Mexico and Arizona.

It was evident that the fall had been widely observed, that it had been of great magnitude, and that it had descended from a southeasterly direction and should have come to Earth somewhere in the region west of Craig, Colorado. We proceeded thither for a more detailed survey.

Following U.S. Highway 40, we reached Maybell, Colorado, before establishing quarters. There it was evident that we had approached very near to the line over which the meteor had descended. Personal interviews in the course of 2 days established the fact that the meteor had crossed over U.S. Highway 40 at a point between Maybell and Cross Mountain Post Office, 15 miles southwest of Maybell. 2 more days spent in interviews to the north and northeast of these points and farther west in Utah established the end point of the meteor as having been some 20 miles northwest of Maybell.



THE GREAT METEOR OF 1941 JUNE 28, AS VIEWED FROM A DISTANCE OF 200 MILES

This painting, by Dexter Floyd Landau of the Colorado Museum of Natural History, was made from the notes of H. H. Nininger. The explosion here represented took place 15 miles above the surface of the Earth. The 3 sparks continued, to within a distance of about 6 miles of the ground, and then were extinguished. The starlike object to the left of the meteor is the planet Venus.

Having located the approximate point on U.S. Highway 40 where the meteor crossed, we proceeded south and southeast to establish another point in its course, so as to ascertain its true direction. The town of Meeker lies 36 miles south-southeast of Maybell. This place seemed to be a good center from which to work. Interviews in Meeker proved that the course had lain slightly to the east of that town, and witnesses from the Buford vicinity made clear the fact that the meteor had passed on the west side of them. Clinometer readings here and in Meeker indicated that it had passed over a point about 5 or 6 miles east of Meeker. We

had now established its direction.

Dr. D. A. Busch, a geologist, who had an excellent view of the meteor from Vernal, Utah, almost exactly at right angles to the line of flight, indicated on a diagram an angle of 24° to the horizontal as the angle of descent. Plotting our own line of observation by the position of Venus at the moment of the passage of the meteor, we were able to ascertain that the brilliant phase of the spectacle ended over a point about 213 miles from our position. At this distance, the correction for the curvature of the Earth and for atmospheric refraction amounts to 4.9 miles. A degree is equivalent to 3.7 miles, and the altitude of Venus was 3°06. The end point of the brilliant phase was about 3° above the horizon. The 3°, accounting for 11.1 miles, plus the 4.9 miles due to curvature and refraction, would give 16 miles as the height at which the great dazzling fireball vanished and from which 3 lesser fireballs proceeded.

It will be noted that I now refer, as "fireballs," to what were previously described as "sparks." This procedure is entirely consistent, for it will be recalled that these sparks appeared to be of the same brightness as Venus did to us that evening, from our position. When we interviewed persons within distances of 20 to 50 miles from the courses of these sparks, they were compared, by these people, to the Moon rather than to the "Evening Star." To a person only one-tenth as far away as we were, the magnitude of what to us compared with that of Venus was a hundred times as great. The nearer observers had watched these (to us) "sparks" travel on some 20 to 25 miles farther and, at a height of some 6 or 7 miles, burst into another shower of sparks which had been entirely invisible to us.

Few of the 97 witnesses interviewed in northwestern Colorado had seen the really brilliant phase of the meteor. They were in the wrong position to observe this. The meteor was too nearly overhead and was coming too nearly toward them. The first thing that attracted their attention was an extremely bright "bluish light all around them." Naturally, by virtue of their previous experiences, they could think of nothing but the light from the headlight of a car, even though this meteoric light did seem different to them from that. They looked all about and, failing to find the light, they finally looked up, but by this time the great change in the meteor had taken place. The brilliant fireball had vanished, and the eye caught one of the lesser, but still very impressive, fireballs and followed it until it disappeared. Some few persons caught a glimpse of the blinding earlier phase and others, who looked too late for the principal display, noticed a peculiar "little cloud" among the other flecks of normal cloud overhead, whence seemed to come the terrific blast or thunderous sound which arrived a little while after all the light had vanished. The fear that these weird phenomena caused left more or less of a confused memory of the event in the minds of these observers. Some did not wish even to talk about it! Disturbing detonations were heard by residents in an area roughly 100 miles in diameter.

A search will be made in due course of time for fragments, a shower of which is believed to have landed on the Earth.

Committee Appointments

The President has appointed the following 2 committees:

Committee on the Legal Ownership of Meteorites: Oscar E. Monnig, Fort Worth, Texas (Chairman); Walter W. Bradley, San Francisco, California; Earle G. Linsley, Oakland, California; Howard A. Meyerhoff, Northampton, Massachusetts; H. W. Nichols, Chicago, Illinois; S. H. Perry, Adrian, Michigan; J. Hugh

Pruett, Eugene, Oregon; Nathan Schwartz, Los Angeles, California; Edward S. C. Smith, Schenectady, New York.

Committee on Terminology: Frederick C. Leonard, Los Angeles, California (Chairman); L. F. Brady, Mesa and Flagstaff, Arizona; Lincoln La Paz, Columbus, Ohio; H. W. Nichols, Chicago, Illinois; H. H. Nininger, Denver, Colorado; F. A. Paneth, Durham, England; L. J. Spencer, London, England.

C. H. CLEMINSHAW, *Secretary*

Ten Years with the Leonids*

I wish to present this review of our work in Southern California upon this famous group of celestial visitors principally because of the extraordinary and surprising display which they afforded this year. Indeed, the recent shower came very near equaling in brilliance the spectacles of 1931 and 1932 when the true maximum was anticipated. The intervening years since 1932 provided very meager displays of Leonids until 1937, when an apparent increase was noticed, but no really outstanding exhibition was witnessed until November, 1939.

Comprehensive observations of the Leonid meteors have been conducted each November from 1930 to date at the Frank P. Brackett Observatory of Pomona College, Claremont, California. In the course of this interval, both visual and photographic programs have been arranged.

The visual observations have been made each year by organized student groups of the Department of Astronomy. Each observing group numbered from four to six members and operated in relay shifts between the hours of midnight and dawn. The dates of observation were chosen to span the 16th and 17th of November each year and were continued for a space of four to seven days.

The photographic program, while not so consistently pursued as the visual, has included single-station, direct photography of members of this stream and also double- and triple-station photography for purposes of triangulation. In 1932, which was apparently the peak year for these meteors, several meteor trails were obtained in spite of some unfavorable weather. Among these, three pairs were identified as simultaneously photographed from two of the three stations at which cameras were placed. This triangulation program was made possible through the kind coöperation of the Mount Wilson Observatory of the Carnegie Institution of Washington and the Solar Radiation Observatory of the Smithsonian Institution, which are approximately 25 miles and 20 miles distant, respectively, from the Frank P. Brackett Observatory in Claremont. From the Claremont station, also, one outstanding meteor was separately photographed on November 17, 1932, which was so brilliant that the photographic emulsion was twice reversed. Since 1932, no photographs of Leonids have been obtained here, although several attempts were made, but this year, again, many bright Leonids appeared which left persistent trains and one of these, whose train endured for twelve minutes, was caught by the camera.

In reviewing the past ten observation periods of the Leonid meteors by visual methods, which is the main purpose of this report, it is noteworthy that the character of the observations and the experience of the observers have been very uniform throughout the whole series. This fact should lend some weight to

*Read at the Seventh Annual Meeting of the Society for Research on Meteorites, Columbus, Ohio, 1939 December 28-30. Communicated by the Editor of the Society.

the value of the comparative figures and any conclusions which seem to flow from them.

As stated previously, the observing groups numbered four to six persons with one serving as recorder. In this way, a record of the serial number, time of appearance, brightness, speed, Leonid or non-Leonid character of the meteor observed, and remarks concerning its train or other pertinent data, such as of the weather, was kept. For the first two or three years a large blue-print map was provided and each observer of a meteor plotted its position upon this map. This practice resulted in the loss of some observations, reducing the total count, but did not affect the statistical value of the observations as a whole. However, since no similar program was being followed at any second station which might provide simultaneous observations for purposes of triangulation, this plan of mapping has been omitted from the observations of recent years.

There are naturally many factors which affect such visual observations, notable among which are the conditions of the weather, the number of observers, and the presence or absence of the moon. In these ways, the total number of observable meteors would be modified, but by considering the percentage of meteors which seem to belong to the Leonid stream, it would appear that comparative figures are obtained which are as nearly as possible independent of these variable factors.

The condensed statistics are shown in Table I and Table II. In these tables, the whole numerical story of the behavior of the Leonids as observed in Claremont in the course of the last ten years is exhibited.

It should be remarked, however, that the importance of a shower cannot be fully indicated by these numbers alone, since the maximum brightness and relative numbers of the outstanding meteors contribute so considerably to the impressiveness of the display. With this fact in mind, it might be urged that the number of

TABLE I

LEONID OBSERVATIONS, 1930-1939, MADE AT THE FRANK P. BRACKETT OBSERVATORY, CLAREMONT, CALIFORNIA

Date 1930	Hour	Total	Leonids	Leonids %	Date 1931	Hour	Total	Leonids	Leonids %
Nov. 13	0—1	6	1	16.7	Nov. 14	0—1	19	2	10.5
	1—2	6	2	33.3		1—2	14	3	21.4
	2—3	11	3	27.3		2—3	16	3	18.8
	3—4	16	3	18.8		3—4	15	7	46.7
	4—5	14	6	42.8		4—5	14	5	35.7
	Totals	53	15	28.3		Totals	78	20	25.6
Nov. 15	0—1	2	0	0.0	Nov. 16	0—1	17	4	23.5
	1—2	4	3	75.0		1—2	24	4	16.7
	2—3	18	2	11.1		2—3	24	3	12.5
	3—4	14	5	35.7		3—4	24	11	45.8
	4—5	17	7	41.2		4—5	20	12	60.0
	Totals	55	17	30.9		Totals	109	34	31.2
Nov. 18	0—1	6	0	0.0	Nov. 17	0—1	50	38	76.0
	1—2	30	4	13.4		1—2	106	91	85.8
	2—3	22	10	45.4		2—3	74	64	86.5
	3—4	27	13	48.1		3—4	105	96	91.4
	4—5	35	15	42.8		4—5	62	10	16.1
	Totals	120	42	35.0		Totals	397	299	75.3

Date	Hour	Total	Leonids	Leonids %	Date	Hour	Total	Leonids	Leonids %
1931					1933				
Nov. 19	0—1	13	2	15.4	Nov. 15	0—1	34	10	29.4
	1—2	19	2	10.5		1—2	32	8	25.0
	2—3	52	27	51.9		2—3	11	3	27.3
	3—4	47	25	53.2		3—4	17	9	52.9
	4—5	46	34	73.9		4—5	27	13	48.1
	Totals	177	90	50.8		Totals	121	42	34.7
1932									
Nov. 15	0—1	5	1	20.0	Nov. 16	0—1	33	17	51.5
	1—2	5	5	100.0		1—2	33	15	45.4
	2—3	16	12	75.0		2—3	33	18	54.5
	3—4	14	13	92.8		3—4	39	28	71.8
	4—5	34	33	97.1		4—5	42	30	71.4
	Totals	74	64	86.5		Totals	180	108	60.0
Nov. 16	0—1	3	3	100.0	Nov. 17	0—1	21	3	14.3
	1—2	10	8	80.0		1—2	35	7	20.0
	2—3	46	41	89.1		2—3	27	13	48.1
	3—4	27	24	88.9		3—4	45	19	42.2
	4—5	16	15	93.7		4—5	46	17	37.0
	Totals	102	91	84.9		Totals	174	59	33.9
Nov. 17	0—1	3	3	100.0	Nov. 18	0—1	20	4	20.0
	1—2	6	4	66.7		1—2	25	8	32.0
	2—3	20	15	75.0		2—3	11	4	36.4
	3—4	46	41	89.1		3—4	39	10	25.6
	4—5	84	72	85.7		4—5	28	10	35.7
	Totals	159	135	84.9		Totals	123	36	29.3
Nov. 18	0—1	9	5	55.6	Nov. 19	1—2	17	9	52.9
	1—2	11	5	45.4		2—3	15	9	60.0
	2—3	11	6	54.5		3—4	51	35	68.6
	3—4	10	7	70.0		4—5	28	18	64.3
	4—5	6	4	66.7		Totals	111	71	65.8
	Totals	47	27	57.4					
Nov. 19	0—1	7	1	14.3	1934				
	1—2	13	6	46.2	Nov. 14	0—1	6	2	33.3
	2—3	14	9	64.3		1—2	21	7	33.3
	3—4	12	6	50.0		Totals	27	9	33.3
	4—5	3	3	100.0					
	Totals	49	25	51.0					
1933									
Nov. 14	0—1	20	4	20.0	Nov. 15	0—1	42	11	26.1
	1—2	18	3	16.7		1—2	38	12	31.6
	2—3	23	3	13.0		2—3			
	3—4	24	9	27.5		3—4	40	12	30.0
	4—5	20	13	65.0		4—5	36	8	22.2
	Totals	105	32	30.5		Totals	156	43	27.6

Date	Hour	Total	Leonids	Leonids %
1935				
Nov. 14	0—1	8	4	50.0
	1—2	9	2	22.2
	2—3	4	0	0.0
	3—4	8	4	50.0
	4—5	3	2	66.6
	Totals	32	12	37.5
Nov. 15	0—1	9	4	44.4
	1—2	23	11	47.8
	2—3	15	7	46.7
	3—4	16	8	50.0
	4—5	16	6	37.5
	Totals	79	36	45.6
Nov. 16	0—1	9	5	55.6
	1—2	19	4	21.0
	2—3	8	1	12.5
	3—4	29	14	48.3
	4—5	33	18	54.5
	Totals	98	42	42.8
1936				
Nov. 16	0—1	40	22	55.0
	1—2	33	13	39.4
	2—3	27	15	55.6
	3—4	33	17	51.5
	4—5	40	26	65.0
	Totals	192	101	52.6
Nov. 17	0—1	15	5	33.3
	1—2	34	9	26.5
	2—3	54	27	50.0
	3—4	36	16	44.4
	4—5	66	30	45.4
	Totals	234	104	44.4
Nov. 18	0—1	43	12	27.9
	1—2	41	18	43.9
	2—3	41	18	43.9
	3—4	50	22	44.0
	4—5	58	23	39.6
	Totals	264	101	38.2
1937				
Nov. 15	0—1	..	..	49.0*
	1—2	..	..	64.3*
	2—3	7	5	71.4
	3—4	20	17	85.0
	4—5	87	72	82.8
	Totals	114	94	70.5

Date	Hour	Total	Leonids	Leonids %
1937				
Nov. 16	0—1	5	2	40.0
	1—2	11	5	45.4
	2—3	35	24	68.6
	3—4	33	26	76.5
	4—5	66	47	71.2
	Totals	150	103	68.9
1938				
Nov. 17	0—1	20	7	35.0
	1—2	50	32	64.0
	2—3	35	19	54.3
	3—4	17	11	64.7
	4—5	18	14	77.8
	Totals	140	83	59.3
Nov. 18	0—1	24	6	25.0
	1—2	25	9	36.0
	2—3	22	11	50.0
	3—4	13	7	53.8
	4—5	14	10	71.4
	Totals	98	43	43.9
1939				
Nov.15	1—2	30	9	30.0
	2—3	43	19	44.2
	3—4	29	8	27.6
	4—5	30	14	46.7
	Totals	132	50	37.9
Nov. 16	1—2	36	20	55.6
	2—3	51	30	58.8
	3—4	53	25	47.2
	4—5	52	39	75.0
	Totals	192	114	59.4
Nov. 17	1—2	39	17	43.6
	2—3	71	41	57.7
	3—4	126	100	79.4
	4—5	264	127	48.1
	Totals	500	285	57.0
Nov. 18	1—2	26	8	30.8
	2—3	33	16	48.5
	3—4	39	18	46.2
	4—5	33	20	60.6
	Totals	131	62	47.3

*Interpolated from averages.

meteors which leave enduring trains for one or more minutes should be taken as an index of peak activity. When judged by this criterion, also, the recent shower of last November was surprisingly near the equal of the displays of 1931 and 1932.

TABLE II

Year	Leonid % of Totals	Dates of Observations	Observing Conditions
1930	31.4	Nov. 13, 15, 17, 18	Late moon. Weather interruptions.
1931	45.7	14, 16, 17, 19	No moon. Slight cloudiness.
1932	73.8	15, 16, 17, 18, 19	Moon near full. Some cloudiness.
1933	42.4	14, 15, 16, 17, 18, 19	No moon. Clear.
1934	30.4	14, 15	No moon. Interruptions by fog.
1935	42.0	14, 15, 16	Gibbous moon. Some fog.
1936	45.1	16, 17, 18,	No moon. Clear.
1937	69.1	15, 16	Moon near full. Some cloudiness.
1938	51.6	17, 18	Late moon. Slight cloudiness.
1939	50.2	15, 16, 17, 18	No moon. Clear.

In comparing the Leonids of 1931 with those of 1939, there is still another type of observation which will bear pointing out, for in both instances bright meteors were observed to travel practically from horizon to horizon, from East to West across the sky, at about 10:45 P.M., P.S.T., before the radiant had actually risen above the eastern horizon. These meteors were undoubtedly Leonids which, on account of their slight upward inclination as they entered the local range of vision in the East, were enabled to maintain a relatively high elevation through most of their path in the atmosphere and thereby to survive longer instead of plunging more rapidly downward to be more quickly consumed as is the case later when the radiant has risen well above the eastern horizon.

In conclusion, it would seem that an unexpected and possibly unprecedented concentration of the Leonid meteorites was encountered by the earth this last November, but the possible relationships between this display and the deflection of the main stream or the position of comets formerly occupying the same orbit, must await discussion at a later date.

WALTER T. WHITNEY.

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Comet Notes

By G. VAN BIESBROECK

No new comets have been announced this month. There are, however, no less than four comets under observation but all of them are faint. In order of decreasing brightness they are the following:

COMET 1941 *d* (VAN GENT) is gradually fading while moving rapidly southwestward. In January it will be an evening object but too faint for ordinary telescopes. When last seen here on December 10, the magnitude was quite close to the value predicted by the ephemeris on p. 543 of the preceding issue.

COMET 1941 *f* (PERIODIC SCHWASSMANN-WACHMANNN No. 2) follows closely the course indicated by the ephemeris on p. 543 but not until next spring will it come in reach of medium-sized instruments.

COMET 1925 II (PERIODIC SCHWASSMANN-WACHMANN No. 1), whose spectacular changes in appearance were mentioned last month has continued to fade

and expand into a more and more diffuse coma. On December 10 its trace could no longer be found on a plate showing stars down to magnitude 17. Further watch is to be kept of this object which, according to previous experience, might flare up again unexpectedly, but it is moving rapidly into the evening sky and soon the observational season will be over for it.

On November 22 I succeeded in locating the faint image of COMET 1933 IV (PERIODIC WHIPPLE) which now comes again in opposition in the constellation of Monoceros. It appeared then as a round coma hardly more than 10″ in diameter and the brightness was not more than that of a 17th magnitude star. This will extend by a year the arc covered by the observations at this apparition. But few further observations can be expected of this inconspicuous object.

Williams Bay, Wisconsin, December 11, 1941.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Predicting Dates of Maxima and Minima for Long-Period Variables: The variations from uniformity in the arrival at maximum and minimum for long-period variables, especially those of the Mira-type, have long been a subject for much discussion. Paul Ahnert, of Sonnenberg, Germany, has recently published a paper in which he raises the question as to which is more expedient, to predict dates of maximum and minimum from an assumed constant period for the star under consideration, or to make use of sine or quadratic terms which would seem to best represent sudden or gradual changes in period. His conclusions more or less agree with those recent investigators, that is, that secondary terms for Mira-type stars have little value for predictions, especially over long intervals. Sine terms may well represent what has taken place in the past, but they serve little purpose for predicting what the star will do in the future.

Ahnert has investigated 15 Mira-type stars which were common to his and Nijland's programs covering an unbroken series of observations of 35 years (1905-1940). For 80 dates of maximum, he finds the mean differences between his own dates and those determined from Nijland's observations to be of the order of 5 days, with a difference of 12½ days for the 10 largest deviations. If we assume a mean value of the period as 300 days, this indicates a mean difference for all 80 maxima of 1.7 percent, or 4.1 percent for the largest deviations.

Of the 15 stars discussed by Ahnert, only two—W Andromedae and R Lyncis—were found for which linear elements represented the entire series of observations between 1905 and 1940. R Aquilae, as is well known, showed a gradual change in period, as does R Hydrae.

Ahnert concludes that if only moderate accuracy in predictions is required, say within 5 percent of the period, simple elements are adequate for the majority of the stars, provided these elements depend on a sufficiently long series of observational data. The use of sine terms only makes matters worse, for the changes are more often abrupt or irregular, rather than cyclical. He suggests the use of "instantaneous" elements, which are assumed to be those elements which are the most up-to-date, and which take into account the recent behavior of the star in

question. He also points out that changes in period as derived from maxima are not found to prevail for the immediate related minima. Accordingly, the intervals from minimum to maximum (M — m) must vary, although not to such a large extent. No specfic rule can be applied for the stars in general; the conditions differ from star to star.

It was recognized at Harvard many years ago that the predictions of dates of maxima and minima from linear or sine term elements was futile. On occasion, the differences between observed and predicted dates exceeded a month, and the average value was nearly 25 days. For this reason, predictions were made there which are based on the use of mean light curves for the individual stars, referred to the preceding, best observed maximum or minimum. Immediately a marked improvement was noted. For the year 1921, the average difference between observed and predicted dates was 12.5 days for the maxima and 15 days for the minima. Expressed in another manner, 33 percent of the predictions were within five days, 56 percent within 10 days, and only 12 percent exceeded 25 days. In 10 years these differences were appreciably improved; $9^d.4$ for maxima, and $10^d.5$ for minima, or 42 percent of the maxima within five days, 67 percent within 10 days, and 6 percent greater than 25 days. When it is recalled that an average difference of at least five days can be accounted for by intrinsic irregularities in the variables themselves, as shown by Ahnert's discussion, this value indicates that the dates predicted by the Harvard method are really almost as good as can be expected. The maxima and minima for stars with long protracted and irregular maxima and minima naturally are more difficult to predict.

An extensive discussion of changes in period of long-period variables was made by Sterne and Campbell in 1936, and the results appear in a paper published in the Harvard Tercentenary Papers.

Variations in Brightness of Maxima of Long-Period Variables: The fact that many of the Mira-type stars attain markedly different magnitudes at maximum and at minimum for the same star has been recognized almost since the beginning of variable star observing. This feature is particularly noticeable in such stars as o Ceti and χ Cygni, in spite of the fact that the Mira stars are considered, in general, as "regular" variables. The elements of the light curves can be said to represent only mean values.

Paul Ahnert has recently discussed the variation in the brightness of the maxima of Mira stars, and his results more or less confirm earlier and contemporaneous conclusions. Joy has discussed the spectra of these stars, which show a variation in intensity of emission lines which depends on the height of maximum, and that for the fainter maxima, new emission lines, not otherwise observed, appear, as do some unknown absorption lines. Also, Merrill finds that the radial velocities appear to be unchanged for different maxima of the same variable.

Ahnert attempts to find a possible relation between intervals between consecutive maxima, and the brightness at the time of the second maximum. He has shown in an earlier paper that, for a given star, faint maxima were, in general, retarded, while bright maxima occurred earlier. In his recent paper, he concludes, from a statistical standpoint only, that the differences between higher and lower maxima are correlated with lengths of the intervals between the maxima: greater range in brightness at maximum being related to the greatest differences in length of the intervals between maxima.

Ahnert's conclusion is of interest in view of the discussion made at Harvard a few years ago of Mira itself. There it was shown that when the interval in time

between two successive rises to a median magnitude (magnitude 6.0) was short, the star rose to a brighter maximum, and conversely that long intervals indicated faint maxima. This discussion is now being extended by C. B. Ford to a large number of Mira stars, and the results of the discussion will be looked forward to with anticipation. The Harvard discussion appeared to give more uniform results when the intervals between successive attainments of sixth magnitude for o Ceti were correlated with the brightness of the following maximum, than when the intervals between consecutive maxima were used.

Dates of Maxima of Long-Period Variables, 1942: The following list contains predicted dates of maxima during 1942 for those long-period variables which attain a mean magnitude brighter than 8.0. Since it is well known that most long-period variables are subject to variations in brightness at maxima, one can expect the actual observed magnitude at this phase to differ somewhat from that cited in the table. Dates of predicted maxima can be relied upon to within 10 days, judging by results of previous years.

Design.	Name	Date of Max.	Mean Max. Mag.
0010*32*	S Scl	12 16	6.9
001838	R And	4 7	6.9
021143a	W And	4 22	7.3
0214*03*	o Cet	5 15	3.4
0228*13*	U Cet	2 19 10 12	7.5
023133	R Tri	7 15	6.0
0250*50*	R Hor	5 22	6.4
0432*63*	R Ret	7 30	7.6
0435*62*	R Dor	11 21	5.3
0443*49*	R Pic	1 2 6 24 12 14	6.7
0455*14*	R Lep	1 1	7.3
0515*33*	T Col	2 11 9 24	7.5
0524*04*	S Ori	11 17	7.9
0617*02*	V Mon	7 7	7.2
0652*08*	X Mon	3 24 8 27	7.3
070122a	R Gem	1 25	7.1
070310	R CMi	7 16	7.9
072708	S CMi	7 12	7.5
0728*20b*	Z Pup	1 8	7.5
081112	R Cnc	5 17	6.8
081617	V Cnc	3 4 12 2	7.7
0824*05*	RT Hya	7 7	7.1
084803	S Hya	3 27 12 8	7.9
0850*08*	T Hya	9 30	7.9
0929*62*	R Car	8 3	4.4
093934	R LMi	8 6	7.0
094211	R Leo	4 22	5.9
1006*61*	S Car	3 22 8 18	5.3
103769	R UMa	4 15	7.5
1144*41*	X Cen	9 8	7.4
1214*18*	R Crv	3 1	7.4
122001	SS Vir	5 3	6.6
123307	R Vir	5 10 10 12	6.9
123961	S UMa	2 21 10 14	7.9
1324*22*	R Hya	2 20	4.2
1327*06*	S Vir	1 2	7.0
1331*55*	RV Cen	11 30	7.0
134440	R CVn	1 24 12 16	7.6
Design	Name	Date of Max.	Mean Max. Mag.
1409*59*	R Cen	7 15	6.0
142539a	V Boo	1 10 9 26	7.5
143227	R Boo	4 8 11 17	7.1
151731	S CrB	9 8	7.0
1518*22*	RS Lib	1 24 8 30	7.6
1528*49*	R Nor	1 6 12 4	7.3
1536*54*	T Nor	7 3	7.0
154615	R Ser	8 31	6.9
154639	V CrB	7 17	7.8
160625	RU Her	1 6	7.9
1621*12*	V Oph	5 26	7.4
163266	R Dra	6 3	7.6
164715	S Her	7 20	7.5
1648*44*	RS Sco	8 14	6.0
1702*15*	R Oph	10 5	7.6
171723	RS Her	4 12 11 17	7.9
180531	T Her	4 25 10 7	7.8
181136	W Lyr	6 18 12 31	7.7
1821*33*	RV Sgr	10 7	7.8
183308	X Oph	4 16	6.8
190108	R Aql	7 2	6.0
1910*19*	R Sgr	4 13	7.3

Design.	Name	Date of Max.	Mean Max. Mag.	Design.	Name	Date of Max.	Mean Max. Mag.
193449	R Cyg	4 24	7.4	210868	T Cep	11 22	6.1
194048	RT Cyg	8 1	7.3	213753	RU Cyg	{ 4 11 } { 11 25 }	7.5
194632	χ Cyg	12 26	5.1				
1951*42*	RU Sgr	{ 1 7 } { 9 6 }	7.0	2219*48*	S Gru	7 29	7.6
				230110	R Peg	12 17	7.9
200938	RS Cyg	1 1	7.2	230759	V Cas	7 23	7.8
2011*30*	RT Sgr	4 16	7.2	2338*15*	R Aqr	2 15	6.4
201647	U Cyg	7 12	7.0	235053	R Cas	12 18	7.1
2044*05*	T Aqr	{ 3 14 } { 10 3 }	7.6	2351*50*	R Phe	9 11	7.5
				2357*15*	W Cet	4 12	7.4

Minima of Algol—January, 1942: Predicted times of minima for Algol, β Persei, for the month of January, 1942, are cited herewith, as computed by Dr. Z. Kopal. All times are Eastern Standard. From observations of minima by Joseph Ashbrook, made in November, 1941, these times are accurate to within about 25 minutes, sufficiently close for observational purposes. Accordingly, actual minima should occur about half an hour later than the predicted times. About 10 hours are required for the variable to pass through a minimum, or five hours to decrease from maximum to minimum, and a like interval of time for resumption of near-maximum light.

	d	h	m	
1942 January	1	8	0	P.M.
	4	4	49	P.M.
	16	4	05	A.M.
	19	12	53	A.M.
	21	9	43	P.M.
	24	6	32	P.M.

This ephemeris can be extended by adding successively a period of 2 days, 20 hours, 49 minutes.

Note on SS Cygni: The recent rise to maximum of SS Cygni, which occurred on November 29-30, was preceded some 12 days before by an unexpected secondary rise to the 11th magnitude. This rise was well confirmed by several observers.

Observers and Observations during November, 1941:

Observer	Var.	Est.	Observer	Var.	Est.
Albrecht	18	21	Heckenkamp	3	6
Ball, A. R.	26	45	Hiett	16	31
Ball, J.	15	15	Houghton	47	47
Blunck	28	28	Howarth	16	16
Bouton	62	100	Jones	81	261
Brocchi	22	45	Kanda	3	53
Buckstaff	6	10	Kearons	102	237
Carpenter	2	2	Kelly	14	14
Cave	1	1	deKock	60	190
Cilley	86	150	Koons	44	56
Cousins	62	99	Leavitt	12	12
Dafter	10	36	Lovinus	40	58
Fernald	202	317	Manlin	64	73
Ford	16	19	Martin	3	3
Giese	11	18	Mason	40	71
Griffin	5	5	Maupomé	46	51
Halbach	58	77	McKeon	1	6
Harris	35	35	Milnes	6	6

Observer	Var.	Est.	Observer	Var.	Est.
Nadeau	46	46	Smith	11	13
Parker	32	32	Topham	25	25
Parks	32	57	Toyek	8	10
Peltier	186	259	Webb	8	8
Reeves	3	5	Vohman	9	9
Rosebrugh	18	72	Weber	16	16
de Roy	9	20	Yamasaki	40	40
Schoenke	8	9	—		—
Sill	49	49	52	Totals	2884

December 12, 1941.

General Notes

Dr. Harlow Shapley, according to a recent announcement, is the recipient of the Pius XI Medal in Astronomy, one of the most distinguished of scientific honors. The award was made to Dr. Shapley in recognition of his remarkable work in determining cosmical distances. The medal is accompanied by 50,000 lire (about $2,500) in cash.

Dr. Harlow Shapley, director of the Harvard College Observatory, was the guest of honor at a dinner at the Harvard Observatory on November 8. More than one hundred astronomers and members of the Harvard faculty were present to participate in the recognition of the completion of Dr. Shapley's first twenty yeras in his present position. President Conant, President-Emeritus, A. Lawrence Lowell, and a number of others spoke on the occasion of this celebration.

The Rittenhouse Astronomical Society met Friday, December 12, at The Franklin Institute for its regular monthly meeting. Mr. Walter H. Haas of the Flower Observatory gave a paper on "Planetary Observations with Ordinary Telescopes." Mr. Haas is leader of a group of American amateurs who are trying to keep alive the almost neglected but important art of visual planetary observations. His talk was profusely illustrated with lantern slides of original drawings.

Astronomical Lectures at Swarthmore College.—During January, 1942, the Department of Mathematics and Astronomy and the William J. Cooper Foundation of Swarthmore College will continue a series of popular lectures on astronomy according to the following schedule:

January 8. Our Sun, by Martin Schwarzschild, Rutherford Observatory, Columbia University.

January 13. Our Cosmical Neighbors, by Armstrong Thomas, Sproul Observatory, Swarthmore.

January 15. Cosmic Rays, by W. F. G. Swann, Director, Bartol Research Foundation.

January 20. The Moving Stars, by Peter van de Kamp, Director, Sproul Observatory.

January 22. Our Milky Way, by Peter van de Kamp.

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